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The ecology and conservation of lapwings *Vanellus vanellus*

edited by

G.M. Tucker, S.M. Davies & R.J. Fuller



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This report is the product of a British Trust for Ornithology (BTO) workshop on *The ecology and conservation of the lapwing* held at Hemel Hempstead, Hertfordshire, on the 12 January 1990. The workshop was hosted by BP Oil UK Ltd. The idea of the workshop was conceived by Dr Graham Tucker whilst working on a BTO research project on winter bird populations on farmland. This BTO project was funded jointly by the Natural Environment Research Council and the then Nature Conservancy Council under a Special Topic Award on Agriculture and the Environment. The workshop was organised by Graham Tucker whilst working under funding from the Environmental Research Fund. The contribution of Dr Rob Fuller to the editing of this volume was funded partly under contract from the Joint Nature Conservation Committee (on behalf of English Nature, the Countryside

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Introduction

Lapwings *Vanellus vanellus* are familiar birds, common inhabitants of the agricultural landscapes which make up much of the north-west of Europe. They live in open situations, where they are easy to observe. They are conspicuous and attractive in both physical appearance and behaviour. It is little wonder that many people have studied them.

Farmland habitats not only comprise much of the European landscape, but also form the 'countryside' with which many people are familiar. Problems with the EC Common Agricultural Policy have raised agriculture on the political agenda. The dramatic effects of pesticides on wildlife, especially in the 1950s and early 1960s, have impressed themselves upon the consciousness of the general public. Moreover, the equally dramatic changes in agricultural methods and cropping patterns, engendered by technological developments and political intervention, have been striking enough to have been noted far beyond the confines of the farming industry itself. Thus interest in the lapwing's environment has been added to interest in the bird itself.

As a result of this interest recent studies, by both professional and amateur ornithologists have focused on this species. The British Trust for Ornithology, whose members have been active contributors to these studies, therefore deemed it timely to bring together the principal lapwing workers for a one-day workshop in January 1990, and BP Oil UK Ltd judged the topic sufficiently important to host the meeting at BP House, Hemel Hempstead. The object of this volume is to present the abstracts of the talks presented during the workshop, plus a major review by Robert Hudson, Graham Tucker and Rob Fuller of lapwing populations in relation to agricultural change.

That review makes it unnecessary for me to draw together the findings of the workshop participants, but some general conclusions are worth considering. It is clear that the management of its habitat is a major factor in the prosperity or otherwise of the lapwing in north-west Europe. The intensification of agriculture during and after the Second World

War, latterly proceeding ever faster under national and EC programmes and made possible by technological advances, appears not to have favoured this bird. Indeed, much the same can be said of many other typically farmland species. The general background has already been spelt out in admirable detail, notably in the Institute of Terrestrial Ecology Symposium volume *Agriculture and the environment* (Jenkins 1984) and in three publications produced by BTO: *Farming and birds* (O'Connor & Shrubbs 1986); *Birds on lowland farms* (Lack 1992) and *Population trends in British breeding birds* by Marchant and his co-authors (1990).

Recently, as politicians have at last become aware of real or perceived overproduction, the value of continued agricultural intensification has been questioned. Unfortunately, the political actions so far taken in response have focused almost exclusively upon reduction in size of the food mountains. Conservationists are pressing for policies to be based on broader and more long-term considerations, such as the use of the countryside for other purposes than just food and timber production. The maintenance of wildlife and a reduction in the extent to which farming consumes fossil fuels (through its demands for energy to make and operate machinery and to manufacture agrochemicals) are seen as important considerations. For the developing debate, a sound understanding will be required of the ecology of wildlife inhabiting agricultural land.

The socio-economic questions raised in the debate are complex. The ecological ones may be even more so. Unfortunately, public attention is focused largely upon the effects of pesticides on wildlife. As a result, a substantial 'pesticides safety industry' has built up; and even within this limited field, most of the effort goes into laboratory testing of the direct toxic effects of pesticides. Field investigations of the indirect impact of pesticides on bird communities in the wild are rare, and are mostly restricted to single sites. The most comprehensive of such studies is that conducted over seven years by the Agricultural Development and Advisory Service of MAFF on the Boxworth Experimental Farm (Cambridgeshire), published in *Pesticides, cereal farming and the environment* (Greig-Smith, Frampton & Hardy 1992). The BTO Common Birds Census was set up initially to

help monitor the impact of agrochemicals on birdlife and has been, through the continued support of the Nature Conservancy Council and now the Joint Nature Conservation Committee (on behalf of English Nature, Scottish Natural Heritage and the Countryside Council for Wales) a productive and useful scheme. However, the almost total lack of support from the agricultural industry for this and other relevant BTO programmes has prevented their enormous potential from being fully realised.

The importance of continued monitoring of and research into farmland birds has been highlighted by recent BTO analyses, which show a continuing and decline in both numbers and range in of the majority of bird species characteristic of farmland (Gibbons, Reid & Chapman 1993 and Fuller, Gregory & Gibbons 1993).

The same is not true of birds in other habitats. There can be little doubt, therefore, that current farming methods are generally detrimental to birds, and probably also to other wildlife.

Of course, agricultural management is not the only factor to affect lapwing populations. Predation may be important especially on land that is intensively farmed and where the birds are already struggling. We shall never really know whether the harvesting of lapwing eggs, once traditional in Great Britain and elsewhere, significantly reduced populations then. Yet some investigation should be made of the impact of hunting in those parts of central Europe where it is still allowed. This is particularly relevant in view of recent analyses which show that some heavily hunted populations of passerines appear to be unable to compensate for the hunting mortality by a reduction in other sources of mortality (Tucker, McCulloch & Baillie 1990).

The Hemel Hempstead Workshop was largely the idea of Graham Tucker and he put considerable effort into it. It would be a fitting tribute if the research recommendations made by Robert Hudson, Rob Fuller and him, at the end of their review, were implemented. More importantly, it would give us deeper insight into how to manage the countryside for the greater benefit of lapwings and other farmland birds,

which bring so much pleasure to so many people in western Europe.

Jeremy Greenwood
Director, British Trust for Ornithology

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Lapwing *Vanellus vanellus* populations in relation to agricultural changes: a review

R. Hudson, G.M. Tucker & R.J. Fuller

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R. Hudson, G.M. Tucker* & R.J. Fuller+ *British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.*

* *Present address: BirdLife International, Wellbrook Court, Girton Road, Cambridge, CB3 0NA.*

+ *Author to whom correspondence should be addressed.*

1. Introduction

Within the temperate zone of western and central Europe, where man has been modifying the landscape for centuries, the lapwing *Vanellus vanellus* has become increasingly associated with farmland throughout its annual cycle. In recent decades, however, this terrestrial plover has experienced increased difficulties as agriculture has become more intensive, through changes in grassland management and arable cropping practices, more regional specialisations in farming, and through extensions of active husbandry to marginal land. Lapwings have declined within, or disappeared from, many lowland areas, and this trend has stimulated considerable research into the species' ecological requirements. However, the results of these studies are widely scattered in the literature, in several languages, and the time is right to produce a synthesis. The present review of current knowledge of lapwing ecology will be limited to discussions of those factors which may influence the population levels of the species. In particular, those factors resulting from man's activities will be examined in detail. Since much of the recent research has been conducted in western Europe (including Britain), the review will concentrate on lapwing populations there and, in particular, on those breeding on farmland.

The objectives of the review are:

1. to examine the long-term spatial and temporal trends in lapwing populations in western Europe;
2. to identify those farming practices which affect lapwing breeding success and/or adult survival;
3. to identify those factors which may control lapwing population levels, and which may have caused the observed changes in distribution and densities;
4. to identify aspects which require further research;
5. to suggest practical means of conserving lapwings.

2. Long-term trends in lapwing breeding populations

2.1 Britain: the period before 1950

For a long time, man has been encroaching upon the lapwing's natural habitats (rough grasslands, wetland fringes, saltmarshes) though concurrently creating suitable substitutes in the form of farmland. This trend has been especially pronounced since the mid-19th century, as human populations of western Europe have increased sharply, leading to the

growth of towns and cities whose inhabitants demanded cheap foods from the countryside.

During the first half of the present century, lapwings were influenced by several opposing trends. This was a period of temporary climatic amelioration (warming) in northern Europe, which enabled lapwings to colonise northern Scotland and the Faeroes and to spread northwards within Fenno-Scandia and the USSR (Kalela 1949). There were also, however, declines at that time in many areas of temperate Europe; these were attributed to habitat loss and excessive egg-collecting, though cause and effect were not then investigated in the rigorous manner of today. In West Germany, for example, lapwings were said to have reached a low ebb in the 1920s and 1930s, but to have increased again after 1940 as more of them took to breeding on cultivated land (Glutz von Blotzheim, Bauer & Bezzel 1975).

In Britain, where adaptation to breeding on farmland is of long standing, there were numerous subjective reports of lapwing declines from the mid-19th century onwards. Excessive egg-collecting for human consumption was often offered as a major cause of decline. However, after implementation of a protective measure, the 1926 Lapwing Act (Alexander & Lack 1944), considerable recovery was reported. This later period also coincided with the nadir of English agricultural recession, in which arable gave way to stock rearing and neglected fields reverted to rough grazing, resulting in conditions that were more favourable for breeding lapwings. Yet, since recession had been severe since the 1890s (except during the First World War years), the 1926 restrictions on egg-gathering almost certainly did play a part in the lapwing increase during the 1930s (Murton 1971).

The first large-scale lapwing survey conducted in Britain, in 1937-38, was directed towards habitat selection (Nicholson 1938; Nicholson 1939), and no attempt was made to review numbers or status changes. Then Fisher (1941) assessed the lapwing breeding population of England and Wales at that period at 175,000 pairs. No revised figure was offered in the lapwing monograph by Spencer (1953), though this author noted that widespread decline in England and Wales had resumed during the

agricultural revival which was generated by the emergency of the Second World War. Presumably decline then, the scale of which was not documented, involved some adjustment to the abrupt farming changes, though four severe winters during the 1940s were also implicated, especially that of 1946/47 (Spencer 1953).

2.2 Britain: the period 1950-1980

The 1940s and 1950s marked the first phase of the modern agricultural revolution, involving mechanisation, land drainage, a major introduction of chemicals for fertilisers and pest control, and large areas converted to arable, especially cereal production. Ministry of Agriculture statistics show that arable land in England and Wales increased by 1.77 million ha between 1930 and 1963, mainly at the expense of lowland permanent grass (O'Connor & Shrubbs 1986). The rather meagre information available for this period suggests that, after initial adjustment, the national lapwing population was more or less stable until the early 1960s. By the time a second British Trust for Ornithology Lapwing Habitat Enquiry was held, in 1960-61, local reports of lapwing gains and losses were fairly evenly balanced and did not indicate that any marked general change in status was occurring (Lister 1964). Nevertheless, recent re-analysis of the 1960-61 data (Shrubbs & Lack 1991) suggests that there may have been some regional changes during this period. There were more reports of decline than of increase in northern and south-western counties but more of stability or increase in the arable counties of central, eastern and south-eastern England. All regional samples were small, however.

Lapwings were affected adversely by the severe winters of 1961/62 and 1962/63. Recovery from these coincided with the onset of the second phase of modern agricultural changes, which lasted until well into the 1980s. This phase was essentially one of increasing intensification and specialisation in farming: greater reliance upon agrochemicals, abandonment of rotations, enhanced regional concentrations on farming types (livestock versus arable), higher stocking rates on improved grass, switches from hay to silage and from spring to autumn sowing of cereals thus greatly reducing spring tillage, plus

the introduction of new crops such as oil-seed rape which is also autumn sown.

These changes were especially noted in the English and Welsh lowlands; and after about 1970 a divergence was apparent between the lapwing population trends of northern and southern counties, as indicated by the BTO Common Birds Census (CBC) (Sharrock 1976). According to the population indices from the CBC, there was progressive decline in the south, although in the north there was a compensatory increase. However, CBC indices have recently been recalculated, after a plot-reselection exercise and a change of datum year (Marchant *et al.* 1990). The revised indices for lapwing are plotted in Figure 1. These indicate a more confused picture. The indication is that lapwings in central and southern England fluctuated between fairly narrow limits for much of the period (with a temporary increase around 1968-70), whilst in northern counties there was a more consistent pattern of increase that was reversed after 1981. According to these indices, the general decline became very marked from the mid-1980s onwards.

Such apparent regional differences must, however, be treated cautiously. Whilst it has been shown that CBC plots are representative of farming practices in central and southern England, this may not be true of the north (Fuller, Marchant & Morgan 1985). Moreover, with fewer plots in the northern samples, the figures derived from these are open to bias from censuses conducted on atypical farms. The data in Figure 1 are based on annual plot samples of 22-38 (mean 30) for the south, but only 8-17 (mean 14) for the north.

During the BTO Breeding Atlas survey period of 1968-1972 (see Sharrock 1976), lapwings were still found to be widely distributed, with breeding season presence recorded in 91.8% of 10 km by 10 km squares in Britain, compared to 65.5% of squares in Ireland. Then, the main distributional gaps in Britain were in the west highlands of Scotland, south-western Wales, Devon and Cornwall. Sharrock offered an estimate of "over 200,000 pairs" for Britain and Ireland combined. Since this was based on an untested assumption of *c.* 70 pairs/10 km x 10 km square, and 78.8% of all occupied squares were in Britain, one may attribute some 160,000 pairs

to the British portion. This figure was, however, clearly an underestimate (see 2.3).

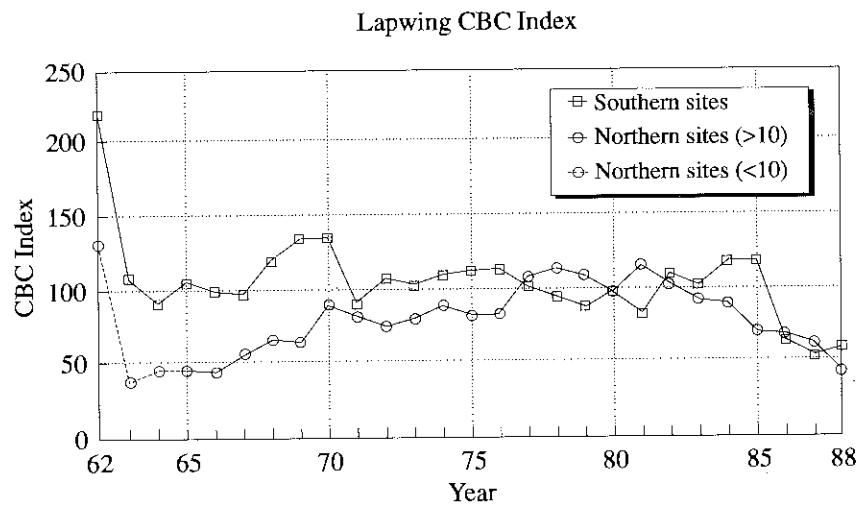
2.3 Britain: the period since 1980

During the 1970s and early 1980s, the national CBC index for lapwing fluctuated between relatively narrow limits (Marchant *et al.* 1990). There was no indication from the CBC that lapwing numbers were affected seriously by the severe winters of 1978/79 and 1981/82; but after 1984 the national index fell sharply, and by 1988 it was only half that for ten years earlier. This suggested strongly that the decline was affecting northern counties also, with agricultural change as the most probable explanation (Marchant *et al.* 1990). Baines (1988, 1994) showed that lapwing densities were lower on improved than on unimproved grasslands in north-east England, a region where much agricultural improvement of upland grass had taken place. In contrast, the BTO Waterways Bird Survey (WBS) indices show little overall change between 1979 and 1988 (Marchant *et al.* 1990), possibly because riverside fields are more likely to include good lapwing habitat, which the birds may occupy preferentially when establishing their territories in spring. Shrubbs & Lack (1991) were of the opinion that the lapwing decline in the 1980s had been exaggerated by the series of cold winters which marked this decade. There is no clear evidence for this in the CBC or Waterways Bird Survey indices. However, these need to be interpreted cautiously in the view of the caveats given above. Additional analysis, still in progress, indicates that there probably was a cold winters effect in the 1980s, which worked together with agricultural changes to tip the balance firmly against lapwings (Tucker, Hudson & Fuller, unpublished).

Within England and Wales, the damp lowland grasslands now hold only a small proportion of the total population of breeding lapwings, numbering fewer than 7,000 pairs in 1982-1983 (Smith 1983), probably only 5-6% of the total. This number has fallen further since then; on a monitored sample of lowland grassland sites, lapwing numbers dropped by 38% between 1982 and 1989 (O'Brien & Smith 1992).

The numbers and distribution of lapwings in England and Wales were assessed by a further

Figure 1. Common Birds Census indices for lapwings in northern and southern Britain, 1962-1988.



BTO enquiry held in April 1987 (Shrubb & Lack 1991, 1994). This was a sample survey of one randomly chosen tetrad (2 km x 2 km) within each 10 km x 10 km square of the National Grid which contained any land. For each tetrad, a complete count was made of the number of nesting lapwings present plus details of the habitats they were using. It was estimated that the lapwing breeding population of England and Wales was then 123,000 pairs, with 95% confidence limits of about 110,000 and 138,000. No less than 96% of pairs located were on farmland. Lapwings were absent from 61% of the sampled tetrads, these being especially those in central and southern England and in Wales, where lapwings are now very thinly distributed; there were particularly few in south-western England and in the western half of Wales. Just over 40% of occupied tetrads and just over 60% of estimated total numbers of pairs were in regions north of a line from the Humber to Cheshire. This comprised about 24% of the total area under survey. The major concentration was confirmed as being in north-western England on the west side of the Pennine ridge, where 75% of visited tetrads were occupied.

For 27 'sites', Shrubb & Lack (1991) compared lapwing numbers in 1987 with those counted in years around 1960, mainly from the BTO Lapwing Habitat Enquiry of that time (Lister 1964). The samples were small and biased

towards tilled farmland, but showed a consistent pattern of decline. This averaged 61% overall, and was least (-23%) in the north-west (Shrubb & Lack 1991). Of course, it was possible that there had been some redistribution by lapwings during these 25 years, so that overall decline was less than this. In comparison, the estimate of 123,000 pairs in England and Wales in 1987 was 30% lower than Fisher's (1941) estimate of 175,000 pairs in the 1930s. Yet the latter figure may have been too low for that period. Fisher did not document the extent of sampling from which his estimate was derived.

The 1987 survey did not cover Scotland. There, Galbraith, Furness & Fuller (1984) estimated from 1982-83 density sampling that there were approximately 64,000 pairs on Scottish agricultural land, including the Outer Hebridean machair. Densities averaged lower in other Scottish habitats, such as moorland and shingle, and Thom (1986) thought it reasonable to place the Scottish total at between 75,000 and 100,000 pairs. Population change there is believed to have been less than in England and Wales, for agricultural intensification has so far been less pronounced, but local decreases associated with grassland drainage and altered arable regimes have been noted (Thom 1986; Marchant *et al.* 1990).

The 1988-91 Breeding Atlas (Gibbons, Reid & Chapman 1993) revealed that lapwings

remained widely distributed but that there had been substantial losses, in terms of occupied 10 km x 10 km squares in Ireland, western Scotland, south-western Wales and south-western England. The combined British and Irish population was estimated at 205,000 to 260,000 pairs.

2.4 Recent trends in continental Europe

We have undertaken a review of the numbers of lapwings breeding in European countries using published information available up to 1991 (main sources: Gromadzka, Stawarczyk & Tomialojc 1985; Piersma 1986; Bartovsky *et al.* 1987; Dominguez *et al.* 1987; Hromadkova 1987; Milsom & Rochard 1987; Devillers 1988; Koskimies 1989; Nankinov 1989; Tinarelli & Baccetti 1989). Outside European Russia and Belarus, Britain, The Netherlands and Finland are believed to hold the most, followed closely by Sweden, but in no other country is the population total believed to reach 100,000. There is a general trend for the highest numbers to be in the northern and middle latitudes of the continent, but simple comparisons are invalid since countries vary greatly in size. Lapwing numbers become lower towards the south, though they have increased there (see below). These countries include mountainous areas that are less suited to this species.

Published overviews of population trends for the 1980s (Sharrock & Hildén 1983; Cramp 1983; Hildén & Sharrock 1985) indicated that lapwings were stable or increasing in most European countries. It should be noted, however, that these overviews are now some ten years out of date and that the situation may well have changed considerably. Note, for example, that severe declines in British lapwings began to manifest themselves in the mid 1980s (Figure 1). A modern southward spread is apparent. Until recently, this applied to a wide longitudinal zone from Spain to the Balkans, but of late, the expansion has halted in Spain. In France, however, there has been a considerable decline which seems to be linked to reduced breeding success on agricultural land (Dubois 1990). Declines have also been reported from Finland and Sweden (Hildén 1989), the Baltic States (Sharrock & Hildén 1983) and from Denmark (DOFT 1989). In

Denmark, the decrease has been attributed to land-use changes, rather than to any climatic factor (Ettrup & Bak 1985). Furthermore, it has been noted that breeding success on intensive farmland in central Europe is below the level required to maintain the numbers of lapwings, which are assumed to be dependent upon immigration by surplus birds reared in more favourable habitats (Imboden 1970; Matter 1982). Further details are presented in section 7.2 of this review.

3. Factors affecting breeding success: habitat suitability

3.1 General background

Lapwing chicks, like those of other waders, are precocial: they leave the nest soon after hatching and are led by their parents to suitable foraging sites. Lapwings can thus exploit the range of field types which are available in areas of mixed farming. In such mosaics, this often means that the birds lay their eggs on bare soil or newly-emerging crops and then, after hatching, lead their chicks to adjacent pasture where livestock grazing keeps the sward low throughout the breeding season, and where the grassland fauna provides a reliable food source for the young birds (Redfern 1982; Galbraith 1987, 1988a). In other faunistically-poor habitats, such as blanket bog, lapwing chicks are also led away to pasture soon after hatching (Redfern 1982). Even within rough grazing areas, chicks will be led from unimproved sections to lush and greener improved grass (Galbraith 1988a, 1988c). These studies, which have demonstrated movements of chicks from one habitat to another, suggest that the optimum conditions for nesting and chick-rearing are different.

The 1987 BTO survey found that 96% of breeding lapwings in England and Wales were recorded on agricultural land, varying from 90% in the south-east to 98% in East Anglia and northern England (Shrubbs & Lack 1991). On the basis of the figures given by Thom (1986), this applies also to up to 85% of lapwings in Scotland. Hence, farmland is the most important habitat type for this species in Britain. In upland regions, lapwings are more likely to be found in valleys than on hills. High

moorland is avoided in Scotland (Brown & Stillman 1993), as also are the exposed uplands of the English Lake District, Wales, Devon and Cornwall. This, however, is probably related to land-use regimes, since lapwings are well-represented in the Pennines where farming is more mixed (Shrubb & Lack 1991).

In Britain there have been three major changes in farming practices which have affected lapwing populations since the 1960-61 Habitat Enquiry by Lister (1964). First, there has been a major switch to autumn sowing of cereals and of oil-seed rape. Hence, autumn tillage has increased but spring tillage has declined. Autumn-sown crops are usually unsuitable by April for nesting lapwings as growth is too far advanced. Furthermore, on many farms the autumn-sown cereals are planted after minimal cultivation following burning of the straw and stubble of the previous crop, so that there has been no conventional ploughing at all. Secondly, pastures have often been drained, reseeded and high levels of nitrogenous fertiliser used to promote grass growth. This either produces too dense a sward for lapwing chicks to move about in, too dry a substrate, or is grazed at a higher stocking rate so that the trampling and desertion risks to lapwing nests are increased. Such grassland improvements can also affect plant diversity and vegetation structure, abundance and diversity of soil invertebrates, and soil pH values (Baines 1988). Moreover, the use of modern leys for silage rather than for hay cropping means more and earlier cuts per season, which may jeopardise chicks. Lastly, there has been a phasing out of rotational farming, accompanied by increased regional specialisation (livestock or arable), so that there is now much less of a farming mosaic in the lowlands which reduces the amount of potentially suitable habitat available to lapwings. As a consequence of these changes, lapwings have become more dependent for nesting upon the much reduced acreages of spring tillage and rough (i.e. unimproved) grassland. These have declined more rapidly in southern Britain than in northern counties (Shrubb 1990; Shrubb & Lack 1991).

3.2 Nest site suitability on tillage

Lapwings show a strong preference for nesting on bare tilled land or on bare patches within sprouting arable crops (Spencer 1953; Shrubb 1990). It is likely that this is due primarily to the existence of:

1. good feeding conditions for egg formation by females;
2. camouflaged concealment of unattended eggs;
3. clearer views of any approaching predators.

Klomp (1954) considered that lapwings could judge the grey-brown or grey-green tints to fields in spring in order to discriminate in favour of those on which plant growth would not become too tall during the nesting phase. Imboden (1970, 1971) noted, in his Swiss study, that dark and as yet unvegetated arable ground was preferred, though agricultural practices there compelled up to 30% of pairs to nest on meadows, these being sub-optimal due to rapid grass growth.

The 1987 BTO survey of England and Wales found that lapwings strongly favoured spring tillage whilst autumn tillage was strongly avoided. The 1937 and 1960 BTO enquiries also reported a preference by lowland lapwings for nesting on bare ploughed land. Furthermore, in 1987 the spring-tilled fields that abutted grass fields were occupied by lapwings more often than would be expected by chance alone, whilst fewer lapwings than expected were breeding on spring-tilled fields that were not adjacent to grass. This pattern is linked to the preference for having adjacent pasture for chick-rearing (see 3.1).

Only 310 pairs were found breeding on autumn tillage in the April 1987 sample surveys, of which 90% were on winter cereals and 10% were on oil-seed rape. In these cases, more pairs than expected by chance were on fields with bare patches (often less intensively farmed), and fewer than expected on fields with tramlines (often the most intensively farmed). In contrast to these small numbers, the 1987 sampling located 1,312 pairs on spring tillage. For these,

the crop type was not always determined since sown fields were often still bare of vegetation in April: 16% of pairs were reported on bare plough; 31% on bare tilled; 36% on spring-sown cereals; 10% on vegetable crops (potatoes, peas, beans); 2% on sugar-beet and 4% on as yet unploughed stubble (Shrubb & Lack 1991).

On autumn-tilled and autumn-sown land, the crop will generally be too tall by April for such fields to be used for nesting (see above). The extensive switch to autumn tillage in England and Wales has served to emphasise the importance of spring plough acreages to the survival of lapwings. Lapwings have declined less in Scotland where a trend towards autumn ploughing did not begin until the 1980s, resulting in a higher proportion of spring tillage still being retained (Marchant *et al.* 1990; Shrubb & Lack 1991). From an analysis of BTO nest record cards for lapwings in England and Wales, Shrubb (1990) concluded that hatching success was higher on tillage than on grass, apparently because lower levels of predation and absence of trampling and disturbance by livestock outweighed the cultivation risks to clutches. Fledging success of birds hatched on tilled land, however, depends heavily upon the availability of alternative grassland feeding sites for chicks (see above).

3.3 Nest site suitability on grassland

In northern Britain the major breeding habitat has been the marginal upland grasslands, and (as mentioned in 2.3) lapwings have declined there where such grasslands have been improved through drainage, reseeding or the application of inorganic chemical fertilisers. Where fields are grazed, such improvements lead to higher stocking rates of cattle and sheep, resulting in increased nest losses through trampling and livestock-caused desertions (Shrubb 1990). Baines (1988, 1994) sought to quantify this deterioration in a northern England study. He found that a mean density of 53.9 nesting pairs/100 ha on unimproved pasture fell by 74% to 14.1 pairs/100 ha on improved pasture. On meadows, the corresponding densities were 59.5 and 26.2 pairs/100 ha, a decrease of 56%. The overall density of 35.3 pairs/100 ha on marginal grass in northern England (Baines 1988) corresponds to densities of 31-39 pairs/100 ha on the machair and blacklands of the Outer

Hebrides, derived from figures given by Fuller *et al.* (1986). All of these figures, however, are well above the mean of only 2.7 pairs/100 ha found for lowland grass sites surveyed in England and Wales in 1982 (Smith 1983).

In the 1987 BTO survey, lapwing densities on grassland showed marked regional variations, none of which were related to stocking parameters. However, there was a general trend for grazed grass to be used in preference to ungrazed, and for leys to be the least preferred of grassland types. Nearly 60% of pairs on grassland were on grazed grass, with the strongest association being with sheep on rough grazing, much of which is unenclosed.

Lister (1964) noted that lapwings leave a site when grass reaches 6 inches (15 cm) in height or cereal is 12 inches (30 cm) tall. These figures were slightly higher than those estimated by Klomp (1954). Lister predicted that lapwings would avoid silage grass because the sward would be too dense and tall for them. This has been confirmed by Shrubb & Lack (1991). The implications of this are serious since silage acreages have increased at the expense of hay-making. In 1985, silage accounted for 26% of all ley and permanent grass in England and Wales (Chalmers & Leech 1986). Lowland hayfields, on the other hand, generally receive lower levels of nitrogen fertiliser, and these are still usable in spring by nesting lapwings. Lower lapwing nesting densities on improved upland grass in northern England may be due ultimately to the more uniform structure of the sward which is created; much of this improved grassland is used for silage (Baines 1988). Such structural changes are believed to result in increased levels of nest predation (Baines 1990). Moreover, reduced breeding success on grazing, due to higher stocking rates, is also implicated (Shrubb 1990). Nevertheless, Galbraith (1988a, 1988c) noted a preference for using improved grass for chick rearing, by pairs which had nested on unimproved rough grazing.

The modern practices of promoting grass growth through the use of artificial fertilisers, coupled with land drainage (one effect of which is to raise soil temperature), are believed to be responsible for a shift in the timing of the lapwing breeding season. In The Netherlands, breeding now begins up to two weeks earlier

than was the case at the beginning of this century (Beintema, Beintema-Hietbrink & Muskens 1985). BTO nest record cards do not indicate any change in the timing of nesting on grassland during the period 1962-1985, but the onset does seem to be earlier than in the period 1940-1961 (Shrubb 1990). Furthermore, the timing of fertiliser applications on cereals now encourages more rapid early growth as well as producing a denser crop (O'Connor & Shrubb 1986). With the lapwing's requirements for short, or no, ground vegetation while nesting, early promotion of plant growth as a consequence of changed agricultural techniques will almost inevitably affect the species, particularly in regard to chick rearing.

3.4 Other factors

Superimposed onto these broad trends associated with land-use changes, there are also local factors which can limit suitability of a site for nesting. For example, significantly lower breeding densities of lapwings have been reported from upland grasslands bordering coniferous afforestation (Stroud & Reed 1986), although it has been suggested that this result may have been a chance effect rather than an edge effect (Avery 1989). Further analyses failed to confirm any significant avoidance of moorland adjacent to plantations by lapwings (Stroud, Reed & Harding 1990). However, Elliot (1982) had earlier noted that lapwings nested significantly further than expected from all trees, and furthest from those which held crow nests, while Berg, Lindberg & Källebrink (1992) recently reported higher nest survival at sites far (>50 m) from trees than at sites close to trees, which suggested that birds were important nest predators. Local nesting numbers are also decreased by disturbance from roads, which follows a logarithmic disturbance profile, and there seem to be similar effects for farmsteads and clusters of other buildings (Van der Zande, Ter Keurs & Van der Zande 1980). It appears that the choice of nesting field is not influenced by food density therein but, rather, by avoidance of nest predation and the proximity of alternative feeding fields for adults and chicks (Galbraith 1989b; Baines 1990).

4. Factors affecting breeding success: food availability

4.1 Adult and chick diets

The food selected by adult lapwings during the breeding season comprises a wide range of ground and soil invertebrates, including earthworms, beetles and earwigs, plus adult and larval stages of flies (especially leatherjackets, Tipulidae), moths, grasshoppers and caddisflies (Lange 1968; Hogstedt 1974; Glutz von Blotzheim, Bauer & Bezzel 1975; Cramp 1983). During the pre-laying period, the birds feed mainly in habitats with high densities of leatherjackets and earthworms, where feeding success is highest (Galbraith 1989b; Baines 1990). Earthworms are a major food source in Sweden during the spring, where the length of the pre-laying period is inversely proportional to lumbricid abundance (Hogstedt 1974). Both earthworms and leatherjackets become less accessible during dry weather, and in those conditions the birds become dependent upon surface invertebrates, especially beetles, earwigs, spiders and moth larvae (Voous 1962). Baines (1990) noted a dietary change by adult lapwings during the breeding season, with concentration on soil invertebrates (earthworms and insect larvae) in April, but on surface-active adult invertebrates (especially beetles) thereafter.

The diet of chicks is varied and opportunistic, including surface arthropods, tipulids and earthworms (Galbraith 1989a). Continental studies have also found that chicks take a wide spectrum of foods, including earthworms and dipteran larvae (especially tipulids) (Matter 1982). Matter (1982) also noted that lapwing chicks are especially likely to be found feeding on field perimeters where spiders and larger beetles are most abundant. Small beetles are common but require too much effort to capture in relation to foraging efficiency. Studies in The Netherlands have reported a clearer dichotomy between the diets of adults and chicks: the latter hunt for surface insects on the ground and vegetation, whilst adults probe for soil fauna (Beintema & Visser 1990b). This, however, is partly at variance with the findings of Baines (1990), quoted above.

4.2 Habitat type and food resources

Cultivated soils, stubble as well as plough, are known to contain lower densities of earthworms than grassland (Edwards & Lofty 1977). This is a result of the combined effects of mechanical damage during ploughing (Zicsi 1958), the loss of insulating material (Evans & Guild 1948), and the low amount of organic matter present (Edwards 1984). Furthermore, soil invertebrates within grass fields increase in abundance with the length of time since it was last ploughed, and are therefore highest in permanent grassland as opposed to temporary grass leys and recently improved grass (Edwards & Lofty 1977; Barnard & Thompson 1985). There is an exception, however: peat soils are always faunistically poor, and contain few earthworms (Satchell 1955; Edwards & Lofty 1977). Within permanent grasslands, the abundance of earthworms is lower on rough grazing than in pasture or other improved grazing (Galbraith 1987, 1988a).

It is not necessary for lapwing nesting fields also to be good feeding sites, provided that productive foraging areas are available nearby. Pastures are important for feeding, for the reasons given above; they are especially important nowadays for chick-rearing by pairs which nested on arable fields. Arable soon becomes unsuitable, as crop growth makes movement difficult within it and reduces visibility for predator detection and avoidance (Galbraith 1987, 1988a). Lapwing chicks hatched on arable are therefore preferentially led to pastures, and chicks hatched on rough grazing and peat habitats are often led to improved grazing nearby. It is for these reasons that a mosaic of crop types presents the best potential conditions for lapwings breeding on lowland farmland.

4.3 Effects of farming practices on food resources

As indicated above, soil invertebrates tend to be fewer in tillage (plough) than in grassland and, in the latter, increase with the age of the grass. However, there can be variations with husbandry practices.

Deep ploughing can decrease soil invertebrate populations by 50%, whereas shallower

cultivation techniques are less harmful. Invertebrate numbers in direct drilled soils were between 17 and 37 times greater than in ploughed soils after eight years (Edwards & Lofty 1975, 1982b). The densities of earthworms and other soil invertebrates are inversely proportional to the period of continuous cultivation (Edwards & Lofty 1975, 1982b; Tucker 1992, 1994). Furthermore, fertiliser applications have marked effects where levels of organic matter are low, as in arable soils. In such soil conditions, applications of organic farmyard manures increase the invertebrate populations; although artificial nitrogenous fertilisers have similar effects, these are more limited (Edwards & Lofty 1982a; Tucker 1992). In general, therefore, the decreased usage of farmyard manures, resulting from the decline in mixed farming enterprises in favour of fast-acting artificial fertilisers, has resulted in a decrease in both diversity and size of most soil invertebrate populations in arable land (Edwards 1984).

The aforementioned does not apply to grass, where higher invertebrate densities already occur as a result of higher levels of organic matter being present naturally in the soil. Applications of farmyard manure to pastures do not increase invertebrate population levels further. However, they do lead to increased surface activity by earthworms (Scullion & Ramshaw 1987), and therefore may make them more readily available to foraging lapwings.

The greatly increased use of pesticides (Potts 1977; Sly 1986) is harmful, not only to the agricultural pests that are being targeted, but also to the invertebrate prey populations of the lapwing. In particular, carbamate fungicides and the molluscicide methiocarb are toxic to earthworms (Edwards 1984; Bieri *et al.* 1989). However, it is the surface-dwelling invertebrates which are most exposed to the effects of pesticide applications, and a number of chemicals have been shown to have deleterious effects upon non-target arthropods. These include the herbicide 2,4-D (Sotherton 1982), methiocarb (Bieri *et al.* 1989; Buchs, Heimbach & Czarnecki 1989), and numerous insecticides, including the organophosphate dimethoate

(Vickerman & Sunderland 1977); the pyrethroids deltamethrin and cypermethrin (Basedow 1985; Pullen 1987); and some synthetic pyrethroids (Smith & Stratton 1986). Clearly, pesticides may have important effects upon food availability for lapwings, particularly in relation to the requirements of chicks when on arable land.

5. Factors affecting breeding success: egg and chick mortality

5.1 General background

The lapwing is a determinate layer in respect of clutch size, normally four eggs, and broods reared per year, one only, but frequently lays replacement clutches for those which have been predated or destroyed. A Dutch study, which incorporated an egg-removal experiment, found that individual pairs could lay up to five clutches per season if necessary and might even replace lost chicks (Klomp 1951). However, experiences in Britain suggest chick replacement is probably exceptional (Jackson & Jackson 1975). Lapwings on farmland therefore have an ability to compensate for losses caused by predation, cultivation and livestock trampling (Berg, Lindberg & Källebrink 1992; Kooiker 1993). It is also possible that lapwings were able to compensate for the large-scale collection of eggs that once occurred in the early breeding season. Not all pairs replace first-clutch losses, however. Baines (1989) found that 73% of pairs replaced first clutch losses on rough grazing whilst only 26% of pairs did so on the suboptimal improved pastures. There may, of course, be territorial shifts by some pairs between nesting attempts. Yet Shrubbs (1990) noted a lower incidence of re-laying on grassland than on tillage in Britain, which he attributed to disturbance caused by higher densities of grazing livestock. The replacement rate also varies temporally. In Dutch meadows, approaching 100% of pairs will re-lay after losses during the first weeks of the breeding season, though the probability of re-laying decreases with the advancement of the season (Klomp 1951; Beintema & Muskens 1987).

There is a temperature-influenced onset to the breeding season, to ensure subsequent

synchronisation with peak food availability for chicks (Imboden 1974; Ettrup and Bak 1985). The consequent later start to the breeding season in northern and eastern Europe restricts the length of the potential egg-laying season there (Cramp 1983).

Now that large-scale egg-collecting for human consumption is a thing of the past, the principal causes of nest failure are predation and agricultural activity, together with desertion for unascertained reasons. Of 1,803 eggs of known outcome that were laid in Switzerland, 23.5% were predated, 11.5% were deserted, and 6.7% were destroyed by farming operations (Glutz von Blotzheim, Bauer & Bezzel 1975). In Dutch studies of meadow birds, 44.0% of lapwing clutches were lost to predation, 22.7% were trampled by livestock, 7.1% were destroyed by farm machinery, and 7.4% were deserted (Beintema & Muskens 1987). On marshland in Schleswig-Holstein (65% arable, 35% grassland), 26% of clutches were predated, 14% were lost through active cultivation, and 9% were trampled by cattle (Matter 1982). Predation was also the most important cause of nest loss in a study of lapwings breeding on Hungarian grassland (Liker 1992). In contrast, on mixed farmland in central Sweden Berg, Lindberg & Källebrink 1992 found that 85% of nest losses were caused by farming operations, although hatching success varied greatly amongst different field types. A study in Scotland, undertaken in pasture, rough grazing and blanket bog habitats, found that the survival probability for individual eggs was 0.9967 per day, or 0.918 over an incubation period of 26 days (Redfern 1983a).

5.2 Predation and disturbance

The figures presented above reveal that as many or more nests are lost to predators as through farming operations; the major exception was the study of Berg, Lindberg & Källebrink 1992, though even in this work, predation risk was shown to be linked with the behaviour of birds. Both the density of nests within lapwing colonies and the size of colonies were negatively related to the probability of nests being lost to predators. Baines (1990) showed that nest predation in northern England was significantly higher on improved grass (76% of clutches) than on unimproved grass (47%). Fieldwork in

Scotland (Galbraith 1988a) confirmed that predation was much more frequent on rough grazing (89.4% of egg failures) than on arable (59.3%), although overall breeding success was lower on arable in that study. This was a consequence of additional egg losses through cultivation and poorer chick survival due to crop growth. In view of the ability of lapwings, in most habitats, to lay replacement clutches after egg losses in March and April, and evidence that birds hatched from late (i.e. repeat) clutches survive at least as well as those from early clutches (Klomp & Speek 1971), it is likely that in many populations chick survival chiefly determines the productivity. High rates of nest losses in May, however, could influence overall breeding success because these late (i.e. repeat) clutches are less likely to be replaced (Matter 1982). A specific example of hatching success influencing overall productivity was given by Baines (1988, 1990). He found that, on improved upland grass, the predation rate on nests was higher than on unimproved fields, and that there was a reduced frequency of laying replacement clutches on improved grassland. This suggests that there can be an interaction between predation and habitat type.

As would be expected, there are regional variations in the importance of predatory species. However, the commonest ones are gulls (Laridae), crows (Corvidae) and certain mammals (especially Mustelidae). Mink *Mustela vison* and polecat *Putorius putorius* figured high amongst predators in a Danish study (Iversen 1986), while in Switzerland the carrion crow *Corvus corone* and black kite *Milvus nigrans* were named as the principal predators (Heim 1978). Heim (1978) noted that there was much annual variation in the extent of predation; while Beintema & Muskens (1987) reported the interesting finding of a link between predation levels and vole (*Microtus*) densities. When vole numbers collapse suddenly after peaks, predators (especially mustelids) turn more to ground-nesting birds as an alternative food source; the link seems to be more with the abruptness of vole population changes than with a simple relationship to vole densities. Experimental work in Wiltshire, involving predator removal, suggests that predator control to protect gamebirds (Phasianidae) might also benefit other ground-nesting species; lapwing

nest survival increased by 61% in that study (Pearson & Stoate 1994).

The effects of disturbance are less readily assessed, but nest desertions from unknown causes will doubtless include many cases in this category. Shrub (1990) has shown that nesting failures on grazed grassland are due as much to disturbance from livestock as to direct trampling. Even livestock damage to a single egg in a clutch can lead to the birds deserting the nest (Beintema & Muskens 1987).

There have been no detailed studies of the effects of human disturbance on lapwing breeding biology. However, it does appear that human disturbance can be harmful, but probably only locally so. On Danish saltmarshes, human intrusions comprised 80% of all disturbances, with lapwings reacting at intruder distances of 70-80 m, compared to 80-100 m for approaching birds of prey, 30-60 m for crows and 15-20 m for gulls (Iversen 1986). The well-known mobbing behaviour of lapwings is effective in reducing natural predation risks. However, there is contradictory evidence about the value of nesting semi-colonially. Galbraith (1988a, 1988c) found that nearest-neighbour distances were more related to quality of the nesting habitat but Berg, Lindberg & Källebrink (1992) found that colonial-nesting lapwings were less at risk from nest predation, as explained above. Moreover, Göransson *et al.* (1975) and Baines (1990) recorded lower losses of artificial nests placed within lapwing colonies than outside. In Polish riverine marshes, waders that are bold in nest defence, notably the black-tailed godwit *Limosa limosa* and the lapwing, have been found to form a 'protective umbrella' for more timid waders such as snipe *Gallinago gallinago* and ruff *Philomachus pugnax* (Dyrcz, Witkowski & Okulewicz 1981). It has even been suggested that passerine field species choose to nest in lapwing territories to take advantage of the lapwings' anti-predator defences (Eriksson & Götmark 1982).

Human disturbance to lapwings is more harmful in non-agricultural sites, especially those used for recreation. A disused airfield colony in the New Forest (Hampshire) declined almost to disappearance when recreational intrusion increased nest losses and chick mortality (Jackson & Jackson 1980).

5.3 Effects of weather conditions on lapwing chicks

Beintema & Visser (1990a, 1990b) have shown that chicks grow faster in captivity than under natural field conditions. In the wild, weight gain occurs after they are at least three days old, and by this stage they may have fallen below their hatching weight. Chicks hatch at the season when the number of dry daylight hours of above 15 °C have begun to rise sharply. Small chicks require at least 25% of daytime hours with temperatures above 15 °C as minimum conditions in which to survive and start growing. Time budgets of chicks comprise alternating spells of foraging and parental brooding, the length of each spell depending upon the air temperature, with rain having an extra cooling effect, and age of the chick. During adverse weather, small chicks need so much brooding to prevent chilling that too little daytime is left for feeding and their growth is retarded. This eventually leads to death if the weather does not improve. Parental brooding ceases above a threshold ambient temperature, this threshold falling as the chick grows older and its own thermoregulation improves.

These summary results are based on Dutch studies which modelled the effects of weather on chick survival. Of course, many previous authors had noted a link between chick mortality and inclement weather conditions. Beintema & Visser (1990a) noted that their growth curves for chicks in The Netherlands showed a much slower rate of growth than was indicated in a study based in Scotland by Redfern (1983b). Weight gains certainly vary between sites, according to their quality as chick-rearing habitats (Ettrup & Bak 1985).

Whilst wet weather interferes with foraging by small and unfeathered chicks, as described above, the availability of prey is increased in conditions of moist soil. Conversely, in very dry weather, when lapwing chicks can forage freely, prey becomes scarcer. In such conditions, the surface invertebrates taken preferentially by lapwing chicks (notably beetles and insect larvae) become fewer and harder to find so that foraging efficiency is reduced (Matter 1982). Moreover, earthworms burrow deeper and

aestivate as the top layers of soil dry out (Edwards & Lofty 1977).

5.4 Influence of farming activities

On grasslands, trampling by livestock is an important cause of nest loss. Moreover, the problem is increased as drainage and fertiliser applications promote grass growth, and so encourage higher stocking rates as well as earlier turning out of cattle that were housed indoors during the winter (Beintema, Beintema-Hietbrink & Muskens 1985; Beintema 1988; Shrubbs 1990). It has been shown that the probability of nest destruction by trampling on Dutch agricultural grasslands is a function of stock density and exposure time. Yearling cattle are the worst trampers in terms of grazing pressure per animal, though the higher stocking density of sheep make these equally hazardous to lapwing nests (Beintema & Muskens 1987). On English hill farms, trampling may not always be the sole problem. Whilst cattle grazing produces an uneven sward, leaving patches in which lapwings can nest, sheep create a more even sward on which incubating lapwings are more conspicuous to predators (E. Ward, *in litt*). Nevertheless, lapwings appear to tolerate sheep more than they do cattle in nesting fields, a tolerance that may be misplaced (Shrubbs 1990).

Nesting on arable farmland also poses risks, and clutch losses are particularly high in the early part of the season due to farming activities (Galbraith 1988a). The highest hatching success recorded by Berg, Lindberg & Källebrink (1992) was on sown tillage but the lowest was on unsown tillage. Successive ploughing, harrowing, seeding, rolling and spraying all destroy eggs laid between these different operations; consequently, repeat layings are frequent (Imboden 1970; Shrubbs 1990). Also, modern cereals grow faster and produce denser crops, due to increased use of fertilisers and to modern sowing methods (O'Connor & Shrubbs 1986). Hence they soon become inhospitable to lapwing broods. Where no suitable chick-rearing pastures are available nearby, this results in reduced overall lapwing productivity on arable land, though success can be higher in years when weather is poor in

spring and cereal growth is less advanced (Galbraith 1988a).

On arable or mixed farmland, adult female lapwings often have access to good quality pre-nesting feeding sites. As a consequence, they can often produce larger eggs which in turn result in larger chicks. However, anthropogenic factors on tilled farmland have decreased the survival prospects for chicks (Galbraith 1988b).

The movement of chicks from their natal field to a nearby feeding area itself poses risks. Most chick mortality occurs in the first few days after hatching. On arable fields these losses are more severe but are concentrated within a shorter period than on unimproved grass (Galbraith 1988a). For their survival, chicks need to be led quickly to suitable feeding areas. Deaths at this time are associated with weight loss and deterioration of body condition which presumably results in chilling (see 5.3). Working in Scotland, Galbraith (1988a) found that chicks which had easy access to pasture survived better after a shorter and less hazardous movement than did chicks which had to be led further from their natal field. But chick survival was best in the one year of that study when poor spring weather retarded crop growth, so that the lapwing chicks were able to remain within their natal cereal fields.

Analysis of BTO nest record cards for the years 1962-1985 has confirmed how agricultural changes have affected the fortunes of British lapwings (Shrubb 1990). Many more nests are now lost for agricultural reasons, compared to the period 1940-1961. Though nest robbing by humans has declined sharply, the incidence of nest desertion has doubled on grassland due to the disturbance caused by the higher densities of grazing livestock. This is in addition to trampling losses. With the additional impact of predation (see 5.2), overall nesting performance on upland grass is now poor, especially on improved grass, with stocking densities inhibiting the rate of replacement of lost clutches. Thus Baines (1989) found that, in northern England, only 17% of eggs laid on improved pasture survived to hatching, compared to 40% of eggs on unimproved pasture. On average clutch sizes are now larger on tillage, where there are fewer partial losses, and mean brood size is larger at hatching. Since

the early 1960s, there has been an increase in the proportion of lapwing nests destroyed by farm operations on tilled land. This is in part due to higher March rainfalls in recent years delaying farming work until lapwings have started nesting (Shrubb 1990). However, these losses are partially compensated for by higher replacement rates for lost clutches on tillage than on grass. Tillage farming may therefore potentially be the better nesting habitat, although the big change to autumn sowing of cereals has limited the amount of spring ploughing, and denied lapwings the good rate of hatching success needed to offset the more difficult chick-rearing conditions on tilled farmland (Shrubb 1990). Again, one sees the advantage of mixed farming types, which are so much less in evidence since the reduced use of rotational farm cropping.

These trends have led to a recent tendency for English lapwings to depend upon minority habitats within regions of farming specialisation. Thus, where there is only a small area of grass in a relatively large area of spring tillage, as in East Anglian arable areas, lapwings increasingly prefer grass for nesting; but where there is only a moderate amount of spring tillage in a predominantly grassland area, there is an overriding preference for the tillage (Shrubb & Lack 1991). Clearly, the presence of both types (spring tillage and grass) is especially important in areas of improved and intensively farmed land.

6. Factors affecting post-breeding and post-fledging survival

The lapwing breeding season draws to a close towards the end of June though a small proportion of young, from replacement clutches, do not fledge until July. The birds gather into flocks from mid-May onwards (initially non-breeders and failed breeders), when non-juveniles begin their protracted annual moult (Appleton & Minton 1978). The post-breeding and post-fledging periods for lapwings therefore encompass the summer months as well as the autumn and winter seasons. No longer tied to breeding sites, the birds can be more mobile in seeking optimum conditions. Outside the breeding season, lapwings congregate into

discrete flock ranges each encompassing several feeding and roosting sites, with such ranges having core areas several kilometres apart (Kirby & Fuller 1994; Milsom 1994). Yet even then they are still influenced by the consequences of modern farming for habitat availability and quality.

6.1 The effects of farming practices

Inevitably, pasture is a key farmland feeding habitat in summer, before mature arable crops are harvested. It has already been stressed (see 4.2) that the highest densities of soil invertebrates occur in permanent grass, the lowest in long-term tillage, with intermediate densities related to the interval since last ploughing. It is not surprising therefore that a range of studies has found permanent grass to be a preferred feeding habitat in autumn and winter, whether airfield or farmland pasture (Fuller & Youngman 1979; Balança 1984; Milsom, Holditch & Rochard 1985; Tucker 1992, 1994). Balança (1984) noted that grass fields were particularly favoured in cold weather. This is consistent with findings in the Vale of Aylesbury (Fuller & Youngman 1979; Kirby & Fuller 1994). There has not yet been any detailed study of the reason for this temperature-related preference, but it does seem feasible that the more dense sward of pasture, compared to winter cereals or even young leys, creates a top-soil microclimate in which invertebrates remain more accessible to feeding lapwings in cold weather (Shrubb 1988). On Nottinghamshire pastures, young leys were used mainly in mild weather, but older pastures with denser swards were preferred during cold conditions (Barnard & Thompson 1985).

A preference for winter cereals has, however, been found in other studies (Gregory 1987; Shrubb 1988), particularly in the early winter when surface activity of invertebrates is greater. This could, of course, include a temperature effect, with mild early winter conditions causing more invertebrates to be close to the surfaces of arable fields and so more readily available to lapwings. Autumn plough is also used, although this is usually only for a very short period of time, presumably because the lapwings confine themselves to searching for prey items turned upwards by the ploughing activity (R.J. Fuller, unpublished).

On mixed farmland in Sussex, lapwings feeding in winter selected winter cereal crops that followed leys or, to a lesser extent, other grass fields. There was a weaker selection for winter cereals which followed an oil-seed rape break-crop and the birds largely avoided fields which had been used for cereals for three years or more (Shrubb 1988). Presumably, this selection was related to availability of prey as fields cultivated continuously over long periods have the lowest invertebrate densities (see above). A preference for winter cereals, despite the availability of grassland, was noted in North Yorkshire also; with a range of crop heights available, the birds made most use of fields in which the young crop was 8-10 cm tall (Gregory 1987).

In a Hampshire study (Milsom, Holditch & Rochard 1985; Milsom 1994), lapwing flocks fed on non-arable sites in June and July when near-mature crops were too tall for use, but occupied a range of habitats in August and September, including much use of arable after harvesting when stubbles had been burnt off or ploughing had started. From October to January there was a strong preference for mown semi-permanent grass, especially for areas which had been kept short by mowing throughout the growing season. The grassland preference continued in February and March, though there was then more use of pastures and meadows, especially after grass had been flattened by snow or frost. However, this study did not always distinguish between feeding and roosting flocks.

Other studies (Kirby & Fuller 1994; Village & Westwood 1994) found pasture was avoided in early autumn, when earthworms were likely to have burrowed deeper into the drying soil. Plough and recently-sown cereals were used then and into the early part of the winter, for they provided an easily exploited food source, although this source declined or became less readily located by the birds as the crop grew. Village & Westwood (1994) reported a crop height of 75 mm to be the critical one above which cereal fields were rarely used. From December onwards, these studies found pastures to be the preferred feeding habitat, even in mild winters, possibly because increasing moisture levels in the ground forced earthworms upwards within the soil profile. Often, individual fields within a flock range will be used over periods of

years, and become traditional feeding sites (Fuller 1986).

The much expanded extent of autumn-sown cereals nowadays seems likely to have increased the availability of early winter feeding sites for this species (O'Connor & Shrubbs 1986). Yet this advantage may well have been offset by increased trends for fields to have long periods under continuous arable/cereal cultivation (i.e. less rotation), high pesticide inputs (including molluscicides), and more frequent applications of inorganic nitrogen fertilisers than of farmyard manure. These practices are likely to have depleted considerably the soil invertebrate densities over much of England's arable farmland (see 4.3).

6.2 Roosting

This aspect has been less studied than has feeding ecology. Certain roost-site preferences have been noted, though evidence is lacking that availability of roost sites influences the survival prospects for lapwings. It has been noted that fields used for roosting are of above average size for the farm or area. In a study in Sussex it was found that 79% of birds used fields larger than 16 ha. This was assumed to be related to improved detection of predators (Shrubbs 1988). In autumn and winter, mammals such as fox *Vulpes vulpes* and stoat *Mustela erminea* may be the principal natural predators, in Britain at least. The vigilance of individual lapwings is reported to be lower in larger fields, so the birds may benefit from increased warning of predators when they are in mixed flocks with gulls (Thompson & Barnard 1983).

Shrubbs (1988) noted that in his Sussex study area, the lapwings preferred pastures for roosting, especially old and tussocky ones with pools for bathing and drinking. Nevertheless, up to 40% of birds roosted on tillage, both plough and winter wheat, so that the majority used different field types for roosting than for most feeding activities. In contrast, a North Yorkshire study found that the same cropping type, winter cereals, was used preferentially for both feeding and roosting (Gregory 1987). In the Vale of Aylesbury, tilled land, especially ploughed or recently sown, was strongly preferred for nocturnal roosting, there being a

camouflage effect. Grassland was used more towards the end of the winter when cereals were growing vigorously; diurnal roosts, on the other hand, were nearly always on large cereal fields (Fuller 1986; Kirby & Fuller 1994).

6.3 Competition

In winter, lapwings often occur in mixed flocks with golden plovers *Pluvialis apricaria*. As they exploit similar species and sizes of invertebrate prey there might be competition between the two species. Thompson (1983) confirmed this prey spectrum overlap, and speculated that golden plovers may peck or probe for prey at shallower depths than lapwings, so reducing interspecific competition. Gregory (1987) also found almost total overlap in field use between these two species.

Lapwings are the regular victims of food piracy by golden plovers, common gulls *Larus canus* and black-headed gulls *Larus ridibundus*. This applies particularly in seasons when earthworms are readily available; and especially in autumn and early spring. Black-headed gulls are able, at least at times, to subsist by kleptoparasitism alone (Källander 1977). Such kleptoparasitism reduces lapwings' feeding efficiency, since they are pressured into taking smaller and suboptimal prey items instead of the larger items which are more likely to be stolen from them (Thompson 1983; Thompson & Barnard 1984; Barnard & Thompson 1985). It is possible that the regular nocturnal feeding by lapwings on moonlit nights (Milsom 1984) is one way by which the species avoids such kleptoparasitism (Fuller 1986).

6.4 Adverse weather conditions

Whilst wet weather is often harmful in the breeding season, causing chick mortality, this is not necessarily so at other times of the year. Rainfall induces earthworm movement to the surface (Edwards & Lofty 1977) and therefore makes feeding conditions easier for lapwings (and their kleptoparasites). Conversely, drought conditions in high summer pose problems through reducing the availability of prey. In such conditions, earthworms burrow deeper and become unavailable; the lapwings turn to less profitable and unusual foods such as caterpillars, earwigs and spiders, they lose body condition,

the incidence of internal parasites rises, and lapwing mortality increases (Voous 1962). Starvation also follows late, heavy snowfall in spring in northern Europe (Vepsäläinen 1968).

Cold weather in winter can be a problem for lapwings, as earthworms move deeper in cold temperatures (Rundgren 1975; Nordstrom 1979). Lapwings can generally cope with nocturnal frosts which thaw by day but their response to prolonged frost and snow cover is to move away for the duration, or even migrate (see 6.5). Judging from the numbers which return to breeding areas the following spring, it appears that particularly severe winters can cause heavy mortality (Spencer 1953). This happened in Britain after the severe winters of 1946/47 and 1962/63. However, it is unclear how much of the decline of lapwings in the 1980s has been attributable to cold winters (see 2.3). It is likely that lapwings are most at risk of cold weather mortality when severe cold extends as far as the Mediterranean, and therefore affects the whole of the European wintering range. Few winters are severe over so wide a spread of latitudes. However, any southwards migration from the British Isles almost inevitably takes the birds into countries where hunting pressure is far higher (see 6.6).

6.5 Movements and migrations

Lapwings are mainly migratory in northern and eastern Europe, where winters are normally severe; but many birds are resident in western maritime countries, except under duress of hard weather. The species' winter distribution reflects a preference for maritime climates during the winter season, and a general avoidance of continental-type weather (Cramp 1983). The overall winter range extends southwards as far as the coastal plains of North Africa and the wetter parts of the Middle East.

The movements of this species were studied in depth by Imboden (1974), through analysis of ringing recoveries. This was also the main source used for the migration account given by Cramp (1983). Major westward movements, comprising adults only, occur through Europe in early summer. These seem to be movements of primarily central European birds. It is likely that the migration urge arises as gonads regress

at the conclusion of breeding, as in other waders, but Schuz (1971) suggested that adult departures then from the drying continental interior helped to reduce food competition for the inexperienced juveniles, which do not move out until the conventional autumn migration season (September - October).

Autumn migrations of all continental populations are mainly in a west-south-west direction across Europe. During this movement many Scandinavian birds enter Britain, but south-westerly movements from south and east Baltic countries largely bypass the British Isles. France, Italy and Iberia are important for wintering. Winter numbers in France are correlated to temperature, and are reduced only in periods of extreme cold (Balança 1984). Numbers reaching or crossing the Mediterranean vary from year to year, according to weather conditions further north.

British lapwings tend to remain local to their breeding area until late autumn, not moving away until cold weather restricts their feeding opportunities (Evans 1966). Subsequent movements may be southwards within Britain, or westwards into Ireland, or further afield into France and Iberia. Analysis of European lapwing ringing recoveries shows that the proportions recovered between September and March within 60 km of the ringing site were highest for Britain (22.5%) and Denmark (21.3%), and lowest (under 3%) for central European countries (Imboden 1974; Cramp 1983). Recoveries suggest that when there are major redistribution movements in severe winters, many of the birds involved do not return northwards until the normal spring migration period, even if the cold spell ameliorates. In Britain, however, areas vacated by lapwings during short spells of severe weather are often reoccupied after completion of a thaw. Such birds had not necessarily travelled far afield in the interim period (Fuller 1986). The flux in lapwing numbers across Britain in response to changing weather conditions during three winters in the early 1980s was described by Kirby & Lack (1993).

6.6 Hunting pressure

Lapwings now have all-year-round legal protection in Britain. This, however, is not the case elsewhere and especially not in southern European countries. Recent increases in the Italian breeding population have been attributed to restrictions imposed upon hunting during the spring (Boano & Brichetti 1986). Estimated winter shooting figures vary from 2,000 per season in Belgium to 1,357,000 in France (Bertelsen and Simonsen 1989), and shooting is also practised on a large scale in Spain, Italy and Greece. Hence, British lapwings moving south in cold winters are at risk from hunters in the countries they reach as well as from the direct effects of hard weather. Moreover, such birds remain at risk for the rest of that winter when they do not return north until the spring migration season.

7. Lapwing population dynamics

7.1 Mortality rates and productivity requirements

Post-fledging mortality estimates have been calculated from ringing recoveries, separately for the first-year and older 'adult' age-classes. Current figures are given in Table 1. The most recent and comprehensive analysis is by Peach, Thompson & Coulson (1994).

Assuming that first-year mortality is in the order of 37% and annual adult mortality is around 33%, then lapwing pairs would need to raise on average one young per year to balance post-fledging losses and maintain the population level (Baines 1989). However, mortality tends to be overestimated by ringing recovery data, in part due to ring loss which affects the older cohorts especially (Evans & Pienkowski 1984). Galbraith (1988a) suggested that lapwing body size, in comparison with other waders, was indicative of a first-year mortality of 35-40% and an annual adult mortality of 25-30%. These estimates would require a mean production of 0.8 young per pair per annum in order to maintain numbers. Matter (1982) calculated that an annual adult mortality of 29.4% in central Europe (Glutz von Blotzheim, Bauer & Bezzel 1975; Table 1) would require a mean

annual productivity of 0.84 young per pair. The analysis by Peach, Thompson & Coulson (1994) indicated that lapwings need to produce 0.83-0.97 fledged young per pair to balance mortality. Yet such figures are merely a rough guide, since mortality rates may vary annually and regionally in accordance with variable pressures, such as weather conditions and hunting levels, in different parts of the species' wintering range. Peach Thompson & Coulson (1994), for example, showed that both adult and first-year survival were related to winter soil temperature and winter rainfall. It has been suggested that adult mortality is low during the breeding season (Baines 1989), but no detailed study of seasonal trends in survival has yet been made.

Breeding productivity figures, from individual studies, are given in Table 2. It is not clear how much significance attaches to the different mean clutch size values; some workers may have been more careful than others to exclude clutches which had experienced partial losses. In BTO nest record cards (Shrubb 1990) the mean clutch size values are 3.63 on grass (s.d. = 0.70, n = 2,269) and 3.78 on tillage (s.d. = 0.54, n = 884), the difference being attributed to fewer partial losses on tillage in the absence of livestock. There are also conflicting views on whether replacement clutches are, on average, smaller than first clutches. No differences were found by Ettrup and Bak (1985) or Galbraith (1988a), while Jackson and Jackson (1975, 1980) found replacements were, on average, smaller. The work of Galbraith (1988a), Baines (1989) and Berg, Lindberg & Källebrink (1992) emphasises that breeding success of lapwings can vary enormously from one habitat type (i.e. field or crop type) to another, even within the same study area.

The hatching success figures in Table 2 show a wide variation. Other than the reserve, marshland and airfield sites, which are little influenced by agricultural activities, there is a tendency for higher hatching success on arable than on grass. Baines (1989) found highest hatching success on arable, followed by unimproved grass, and especially low hatching success on improved grass. Discounting very low hatching success on unsown tillage, where many nests were destroyed by farming operations, Berg, Lindberg & Källebrink (1992)

Table 1. Estimates of lapwing mean mortality, derived from ringing recoveries.

Region of sample	First year mortality (%)	Annual adult mortality (%)	Reference
Britain & Ireland	37.5	33.9	Glutz von Blotzheim, Bauer & Bezzel 1975
Central Europe	40.1	29.4	Glutz von Blotzheim, Bauer & Bezzel 1975
Scandinavia	40.4	33.1	Glutz von Blotzheim, Bauer & Bezzel 1975
Denmark	c. 44.0	c. 33.0	Bak & Ettrup 1982
Britain	29.5	24.8	Peach, Thompson & Coulson 1994

also recorded higher hatching success on tilled land than on grassland or fallow. Particularly relevant here is the nest record card analysis by Shrubbs (1990), based on much larger samples of nests than it is possible to obtain in individual field studies. He found a higher brood size at hatching on tillage than on grassland, but with the mean figures declining over time in both habitat types. During the period 1962-1966 the mean brood sizes at hatching were 2.78 on tillage and 2.32 on grass, but by 1982-85 they had fallen to 2.27 and 1.89 respectively.

The pre-fledging mortality of chicks is high, exceeding 75% in some assessments (Table 2). In relation to this, the figures in Table 2 show a clear difference between grass, especially rough grazing, and arable. As stated earlier, a mean annual figure of at least 0.8 young per pair needs to be fledged in order to maintain population levels (Matter 1982; Galbraith 1988a; Peach, Thompson & Coulson 1994). This figure is reached or exceeded in most of the rough grazing/ unimproved pasture studies in Table 2, but not in any of the arable or improved grass assessments there.

However, Van Impe (1988) reported a mean productivity of 1.45 - 1.58 young per pair on Belgian arable farmland. This seems remarkably high, in comparison with studies in Table 2, but Belgium is a country where lapwings have increased considerably in recent years. The disused airfield study (Jackson & Jackson 1975, 1980) is interesting. During the

first part of the study the output of young was satisfactory and the population level was stable, but during the second phase there was much

increased human recreational disturbance of the site, lapwing productivity was halved and the population level fell.

7.2 Natal philopatry and sink populations

Young lapwings often return to the vicinity of their birthplace to breed (Spencer 1953; Evans 1966) although the incidence of this has never been adequately quantified. This is one of the major areas needing further research. Heim (1978) recaptured, at his study site, lapwings which had been ringed there up to 14 years previously; but his recaptured samples were small in relation to the numbers ringed there during his long-term study. Nevertheless, the proportion of breeding adults returning to an area in the following year is higher than the return rate for one-year-old birds, even after taking differential survival rates into account (Onnen 1989). European ringing recoveries indicate that c. 70% of lapwings which survive the winter return in spring to within 20 km of their natal areas (Cramp 1983).

In contrast, lapwings ringed as chicks have also been recovered in subsequent summers far from their natal areas. For example, Dutch- and British-bred birds have been found in the USSR, perhaps through having joined migrating flocks in spring. It has been suggested that such gene-

flow is regular and has been responsible for inhibiting subspecific variation across the huge Palaearctic breeding range of the species (Evans 1966; Mead, Flegg & Cox 1968). In spring recoveries (1 May - 14 June) of post-juvenile lapwings (i.e. ringed in an earlier year), 88% of those ringed in the British Isles were found within 50 km of their ringing site, with an overall mean displacement of 133 km. In the temperate zone of continental Europe 78% were found 0-50 km from where they were ringed and the mean overall distance was 245 km, whilst the corresponding figures for Scandinavia were 77% and 115 km (Imboden 1974). By no means are all lapwings faithful to their natal area, with local population levels being influenced by immigration and emigration, as well as by local breeding productivity.

Given the evidence that lapwings can settle, in a subsequent spring, a few or many kilometres from their natal area, one can see how the species may persist over a period of years in suboptimal breeding habitats such as tillage and improved grassland. Various recent studies have noted how productivity has become too low on arable farmland to balance adult losses; examples are Galbraith (1988a) in Scotland, Shrubbs (1990) in England and Wales, Ettrup and Bak (1985) in Denmark, and Matter (1982) in West Germany and Switzerland (see also Table 2). Such unfavourable habitats become effectively 'sink areas', absorbing surplus territory-seekers from elsewhere which are unlikely to be able to breed successfully enough to replace themselves.

7.3 Factors influencing population levels

This review has identified a number of factors that have the potential to influence lapwing population levels. These are summarised diagrammatically in Figure 2, although their individual importance differs markedly between areas of grass- and arable-dominated farmland. Such factors may influence population levels either by limiting the size of the breeding population (through a shortage of suitable habitat) or by affecting productivity or survival.

Although individual studies have been able to establish various measures of lapwing breeding

productivity, there has been no overall assessment of the population dynamics of the species. Thus, the relative contribution of each stage of the life cycle to the eventual population level is in doubt though, as explained below, evidence is now emerging that the main problem lies with inadequate production of fledged young. Furthermore, it is unclear how or to what extent the population levels of lapwings are influenced by density-dependent regulation. Galbraith (1988c) found no evidence for density-dependent effects upon hatching or fledging success; but his data on the temporal and spatial patterns of lapwing territories suggested strongly that territorial behaviour exerted a density-dependent effect through excluding other lapwings from good-quality nesting habitats. It is difficult to see how lapwing populations could behave as they do without quite strong density-dependence somewhere in the system. The very idea of 'sink populations' (see 7.2) implies that competition occurs.

Additionally, survival may prove to be density-dependent, in which case the estimates from regional combinations of ringing recovery data may be misleading with respect to the levels of productivity required to balance them. Given the extremely low productivity in improved grass and arable areas, and the fact that lapwing populations are declining in those areas, it is clear that even if there is a density-dependent effect, this cannot be fully compensatory. Furthermore, the low productivity suggests strongly that there is little potential density-dependent compensation for fluctuations in overwinter survival rate. Hence a full population biology study of lapwings, using a K-factor analysis approach (Varley & Gradwell 1960), is required to establish which stages of the life cycle are most important in determining population levels. Such information would be invaluable for targeting conservation measures, and maximising their effects on population levels.

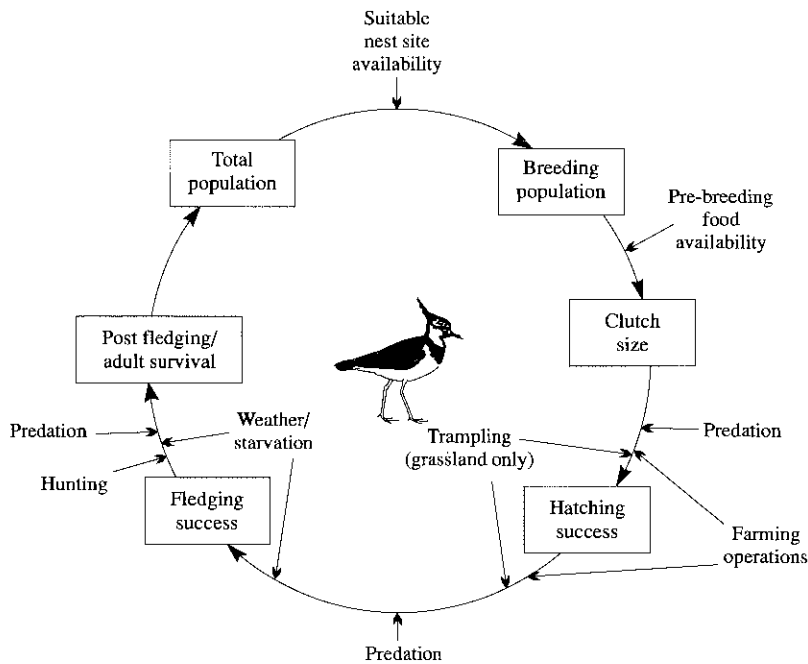
Despite the gaps in our knowledge concerning the factors influencing lapwing populations, it is likely that the observed population decline in many areas is due at least in part to two factors. These are, first, a reduction in suitable nesting habitat and, second, a reduction in productivity

Table 2. Breeding success of lapwings shown by different studies.

Habitat	Mean clutch size	Hatching success (%)	Fledging success (%)	Productivity (fledged young per pair)	Reference
Grassland (part reserve)	3.83	58.4	?	1.46	Heim (1978)
Unimproved pasture	3.73	39.9	35.5	0.92	Baines (1989)
Unimproved meadow		32.3		0.60	
Rough grazing	3.74	34.3	24.4	0.8	Galbraith (1988a)
Marsh (some arable)	3.70	40.0	33.2	0.8	Matter (1982)
Rough grazing *	3.75	77.9	23.9	0.88	Reworked from Jackson & Jackson (1975, 1980)
a) 1971-74 (stable population)					
b) 1975-1978 (population decline)	3.72	65.8	15.0	0.44	
Improved pasture	3.61	16.7	21.5	0.31	Baines (1989)
Improved meadow		22.3		0.23	
Grass (1962-85)	62/66	63.2	-	-	Shrubb (1990)
	82/85	51.9			
Grassland	3.80	53.5	-	-	Liker (1992)
Mixed farmland (70% grass)	?	63.5	?	0.55	Kooiker (1984)
Mixed farmland (44% grass)	3.79	58.8	14.7	0.33	Onnen (1989)
Arable	3.74	45.6	23.5	0.57	Baines (1989)
Arable	3.75	28.2	14.7	0.4	Galbraith (1988a)
Intensive arable	3.80	39.1	13.9	0.35	Matter (1982)
Tillage (1962-85)	62/66	75.5	-	-	Shrubb (1990)
	82/85	60.0			

* Disused airfield

Figure 2. Potential factors influencing lapwing populations.



of nesting pairs. Suitable nesting habitat has decreased most on lowland farms where spring cereals have been replaced by autumn-sown crops which are too tall and dense in spring for nesting lapwings. Similarly, much lowland grass has been reseeded and heavily fertilised for silage production, and this is also avoided by the lapwings.

Productivity is now very low for nesting lapwings on improved grassland and arable farmland and in both cases is probably normally too low to maintain population levels (Table 2, Peach, Thompson & Coulson 1994). Clearly, this must either be a recent phenomenon or lapwing populations breeding in these habitats have long been maintained by immigration from other populations having higher productivity (i.e. source populations). Alternatively, adult survival may have decreased and thus created a need for higher productivity. However, a recent analysis of long-term survival rates of both adult and first year British lapwings gives no evidence that this has happened; adult survival has actually increased in recent decades (Peach, Thompson & Coulson 1994). The problem, therefore, does not appear to lie outside the breeding season. It seems more likely that a general decline in lapwing breeding productivity has occurred. Indeed, Shrubbs (1990) has shown

that hatching success has decreased over time in both grassland and arable farmland.

Low productivity by lapwings on improved grass is at least partly attributable to the current high stocking rates of cattle and sheep, permitted by the drainage, reseeded and fertilisation of what was previously rough grazing. Government subsidies based on number of animals encourage increased stocking rates independent of grassland management. Although lapwings on grass prefer to use grazed fields for nesting (because ungrazed grass is often too tall and dense), the most agriculturally-efficient stocking rates are devastating, due to the high trampling risk and related levels of nest desertion (Beintema & Muskens 1987; Shrubbs 1990).

Predation is also a potentially important factor affecting lapwing productivity on farmland. Low productivity on improved grass was found in one study to be most consistently attributable to variation in hatching success between improved and unimproved grass as a result of differing nest predation rates between the two types (Baines 1989, 1990). However, other studies found that although lapwing nests were subjected to high predation levels, the birds compensated by their readiness to lay repeat clutches. Furthermore, these seem not to be

significantly smaller, only two studies having reported the contrary (Jackson & Jackson 1975; Baines 1989). Nor is there any reduction in juvenile survival from that achieved from first clutches (Klomp & Speek 1971). Clearly, the degree of compensation for nest losses requires further investigation.

The low productivity on arable is mostly attributable to chick losses through predation. One possible cause of the lapwing decline therefore, on both grass and arable habitats, is an increase in predator populations. However, although magpies *Pica pica* and crows *Corvus corone* have increased substantially on farmland since the 1960s (Marchant *et al.* 1990), there is no evidence that this has led directly to increased predation rates on chicks over the period. Indeed, egg predation rates have remained unchanged (Shrubbs 1990). Instead, it seems likely that the high predation rates on arable farmland are attributable to the increasing need for chicks to be moved large distances from arable to grass fields for rearing. Chicks hatched in fields alongside grassland showed substantially higher survival rates than those that were led across several fields to find grass (Galbraith 1988a). Thus it appears that chick survival is closely related to the extent of necessary movement, which is itself related to the proximity to grass. Galbraith's study also suggests that the requirement for movement is not necessarily to find better feeding conditions, but to avoid fields with tall vegetation. However, further clarification of this is clearly needed. Cereal-grass rotations have decreased substantially over the last 10-20 years as a result of increased reliance upon artificial fertilisers and the greater tendency for regional agricultural specialisations. The former mosaic of arable and grass would have provided many opportunities for nesting in cereals alongside grass. Consequently, chick movement and predation risk would probably both have been less, and overall productivity might then have been sufficient to sustain the population level. Hence it appears that the provision of suitable nesting fields (e.g. spring cereals) would not alone be sufficient to maintain lapwing populations on arable farmland, unless coupled with the provision of adjacent grass fields for chick rearing in order to improve breeding success. It is also important that such grass fields should contain wet or damp areas, for the

young will not survive in dry pasture; grassland drainage during agricultural improvements has certainly been harmful to lapwing productivity (P.S. Thompson, pers. comm.).

We have discussed the potential impact of pesticides on the food resources of lapwings (section 4.3) but it should be acknowledged that there may have been additional direct effects of pesticides on lapwings, acting through reduced breeding performance or reduced survival. Indeed, it has been suggested that dieldrin levels may have contributed to some regional declines in lapwing populations (Beyerbach *et al.* 1988). We are unaware, however, of any detailed study of the possible long-term influences of pesticides on the population dynamics of the lapwing.

8. Requirements for future research

This review has highlighted many gaps in our knowledge of lapwing ecology which are relevant to the successful conservation of the species. Furthermore, where information is available, the data are often derived from a small geographical area, few seasons, and a restricted range of environmental conditions. There is a need, therefore, to repeat several of the studies in other areas, particularly the estimation of breeding performance and survival. Future research should include studies of both stable and decreasing populations. Also listed below are priority areas for research that could be aimed specifically at providing new information to help target conservation measures. The list follows a suggested order of priority.

1. A full population biology study by K-factor analysis (Varley & Gradwell 1960) to establish: (a) the stages in the life cycle that are most important in limiting populations size and (b) how density-dependent regulation occurs.
2. An assessment of site fidelity and natal philopatry to establish the role of immigration in the maintenance of sink populations.
3. A detailed study of overwinter survival using ringing recoveries, to establish

whether survival rates have changed and whether such changes are related to trends in agricultural practices or weather.

4. An investigation of the potential role of 'nesting habitat islands' in providing suitable nesting sites in otherwise unsuitable farmland. For example, tilled or rough grass strips might be placed through the centre of winter cereals or (particularly) across improved grass fields, as part of the current set-aside scheme. A similar concept might be applied to chick-rearing. It is possible that in areas of cereal farmland, set-aside fields might offer suitable feeding habitat for chicks that have hatched on adjacent cereal fields. Hence, the potential importance of set-aside to lapwing populations needs to be examined.
5. Experimental studies on the effects of predator control on lapwing breeding productivity in grassland and arable.
6. An assessment, using ringing recovery data, of geographical and temporal variation in the hunting pressure on lapwings outside the breeding season. If sufficient ringing data are available, this should be combined with an assessment of the effects of hunting on average survival rates.
7. A further examination of the effects that farming practices, particularly pesticide applications, have on food availability for lapwing chicks and adults and the resulting risk of starvation. This should include the use of molluscicides and aphidicides in autumn and winter (on autumn-sown cereals), and the impact of the straw burning ban which came into force in 1993.

9. Potential strategies for lapwing conservation

It is clear from the information currently available that any strategy for lapwing conservation must include two major actions if it is to achieve success. Firstly, prime nesting habitat needs to be protected and ultimately increased in extent to ensure that 'source'

populations are at least maintained. Secondly, assuming that adult survival rates cannot easily be influenced, measures must be taken to increase breeding productivity in 'sink' populations. Probably the most practical and efficient means of achieving these goals will include the following actions:

1. Protect existing areas of rough grazing supporting sizeable numbers of breeding lapwings. Probably this could best be achieved by educating landowners, combined with a campaign for some form of compensation scheme to maintain rough grazing. Such compensation could be administered within the framework of the current Environmentally Sensitive Areas (ESA) scheme, but would require the latter's extension to wider geographical units. Except in cases involving extremely high densities of nesting lapwings, protection of rough grazing sites by land purchase would be inefficient and probably would not contribute greatly overall to lapwing conservation.
2. Encourage the spring sowing of cereals as opposed to autumn sowing, where such fields can be placed alongside areas of non-silage grass. This would re-create a farmland mosaic of spring cereal and grass to provide suitable nesting areas and high quality feeding habitats. The success of this would be dependent upon the two components being alongside. The encouragement of spring cereals for suitable nesting habitat will not alone increase population levels - adjacent chick rearing sites must be present also. Again, this goal might best be achieved by education and a campaign for a compensation scheme within the current ESA framework, but it would have little effect if comparatively small areas were involved. There would be more potential if spring cereal and non-silage grass production were encouraged through a wider 'agricultural extensification' scheme.
3. Assuming that set-aside fields will remain a feature of lowland landscapes for several years to come, as a part of the CAP reform measures, opportunities offered by these for lapwing conservation should be developed.

To do so effectively, however, would require further research (see Section 8).

4. Inform farmers of the effects of livestock trampling and farming operations on lapwing breeding success, and encourage them to take avoiding action when practical. Many farmers are sympathetic towards lapwings, and would be amenable to conserving them if the necessary steps were economically viable. Where possible, cattle and sheep should first be turned out onto fields other than those known to have breeding lapwings, with the latter fields being used at a later date. Some agricultural operations could be delayed until the second week in June - after the main nesting period according to laying data from Shrubbs (1990) and incubation data from Jackson & Jackson (1975) - with little cost to the farmer. Rolling is best avoided on lapwing nesting fields, and when rolling is strictly necessary it would be preferable to roll straight after drilling. Alternatively, nests could be located and marked (carefully and inconspicuously to avoid increasing predation) so that tractor drivers could avoid them. Such practices are already carried out successfully on some farms, sometimes with the help of local birdwatchers who take on the task of nest location and marking. This practice should be encouraged through a co-ordinated campaign of articles in birdwatching and farming magazines, and combined with a scheme where farmers with lapwings are put in touch with interested local birdwatching groups. Individual advice will be necessary in many cases, because different soils and crops lead to different management practices.
5. Traditional lapwing wintering sites should be protected where possible, by education and, where necessary, by objections at planning enquiries. This should apply especially where wintering numbers regularly exceed nationally (10,000) and internationally (20,000) important levels (Prater 1981, Scott 1982). Such sites are normally large, open grazed areas of long-established grassland which often receive large inputs of organic farmland manure.

These attributes should be maintained on such sites.

6. A general public awareness campaign should be carried out covering the decline of the lapwing and its likely causes. The main benefit of this would be to create public pressure and backing for agricultural policies that take into account the environmental implications of farming practices. General information reaching landowners might also provide further encouragement to carrying out appropriate conservation measures. Commercial sponsorship of further research would also be more likely if the issue were widely publicised.

10. Summary

1. This paper reviews current knowledge of the ecology of the lapwing, especially in relation to its use of farmland. Specifically, the paper seeks to identify the likely causes of recent declines in lapwing populations that have become evident in western Europe. Critical gaps in knowledge are identified and appropriate research is suggested to provide the necessary information in order to allow a conservation strategy to be developed for this species. Key points emerging from this review are summarised below.
2. According to analyses of trends revealed by the BTO Common Birds Census there have been strong declines in lapwing populations since the mid 1980s, both in southern and northern Britain. There is independent evidence, based on special surveys of the species, that there was an overall decrease in breeding lapwings in England and Wales of the order of 60% between 1960 and 1987. Recent declines have also been reported in Scandinavia, some Baltic countries and in France. There has been widespread concern that changes in agriculture are responsible for these declines in lapwing numbers.
3. A survey of breeding lapwings in 1987 in England and Wales showed that 96% were

on farmland. Farmland is also the most important habitat in Scotland where as many as 85% of lapwings are found. Damp lowland grassland now holds a very low proportion of the total numbers in England and Wales. Three major changes in farming practice are considered to have been of particular significance in altering habitat availability for lapwings. Firstly, the switch from spring-sown to autumn-sown crops has caused a loss of suitable nesting habitat because bare, or sparsely vegetated, tillage is a preferred nest site. Secondly, the drainage, reseeding and more intensive management of pasture has created thicker, taller swards which are unsuitable feeding habitats for chicks, and has permitted higher stocking rates leading to elevated risks of trampling and perhaps predation. Thirdly, the phasing out of crop rotations has led to reduced diversity of crop types, which is significant because lapwings that nest on lowland arable crops often lead their chicks to other habitats nearby, especially grassland, where feeding conditions are better for them; mosaics of crop types present the best potential conditions for lapwings breeding on lowland farmland.

4. Changed farming practices are thought to have reduced the suitability of arable crops as feeding habitats for lapwings and their chicks in three main ways. Decreased usage of farmyard manures has led to a reduction of soil invertebrate populations. Surface-dwelling invertebrates are deleteriously affected by a range of pesticides. The trend towards continuous cropping of winter cereals will have depleted populations of soil invertebrates. These changes will have affected food resources for lapwings both in the breeding season and in winter.
5. Lapwings often replace lost clutches, especially those that are lost early in the breeding season. Hence, they have some ability to compensate for losses caused by predation, farming operations and trampling by stock. Some studies, however, have found relatively low rates of clutch replacement on grassland, perhaps due to disturbance by stock. With a few

exceptions, as many or more clutches are lost to predators than to farming operations. Predation rates are generally higher on grassland than on arable land.

6. Hatching success on tillage has generally been found to be higher than on grassland, probably because losses to farm operations on arable are often exceeded by predation and trampling on grassland. (There are, however, considerable losses on arable land where cultivation occurs after egg-laying.) There may be variations in hatching success on grassland, and one study has shown hatching success to be considerably higher on unimproved grass than on improved grass. In view of the ability to replace lost clutches, and evidence that birds survive equally well from early and late clutches, the productivity of many lapwing populations appears to depend on chick survival. Fledging success, and hence overall productivity, of birds hatched on tilled land depends on availability of adjacent grassland as feeding habitat for the chicks.
7. More information is needed on natal philopatry, but it is clear that lapwings can settle, in a subsequent spring, some kilometres from their natal site. Several studies have shown that breeding production in some arable areas is now too low to offset adult losses. Lapwing populations in these areas appear to persist by immigration of surplus birds; the breeding success of these individuals is unlikely to be sufficiently high to maintain numbers. Hence, it seems that some areas of arable farmland have become 'population sinks'. A similar situation is also probably found on much improved grassland. There is no evidence that survival of British lapwings has decreased. It therefore appears that the causes of the decline lie with inadequate breeding productivity.
8. There is a need for a detailed study of the population dynamics of the species to determine at which stages of the life cycle factors are operating which determine population size. Despite gaps in knowledge about how lapwing populations are limited and regulated, available evidence suggests

that at least two components underpin the decline. First, a reduction in availability of suitable nesting habitat and, second, a reduction in productivity of fledged young.

9. Low lapwing productivity on arable farmland is probably mainly a consequence of poor chick survival due to the scarcity of good chick-rearing habitat. Low productivity on improved grassland is at least partly attributable to high stocking rates of cattle and sheep, but predation rates on clutches also appear to be higher on improved grass. The role of predation is also potentially important in arable systems. There is no evidence that increased predator populations, notably crows and magpies, have directly led to higher predation rates on eggs or chicks. It seems likely, however, that chicks have become more vulnerable to predators because they generally have to move longer distances from the sites where they hatched to find good feeding habitat.

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Breeding distribution and abundance of lapwings *Vanellus vanellus* in England and Wales in 1987

M. Shrubbs & P.C. Lack

Shrubbs, M., & Lack, P.C. 1994. Breeding distribution and abundance of lapwings *Vanellus vanellus* in England and Wales in 1987. In: *The ecology and conservation of lapwings Vanellus vanellus*, ed. by G.M. Tucker, S.M. Davies and R.J. Fuller, 34-36. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 9.)

M. Shrubbs, Hill Crest, Llanwrtyd Wells, Powys, LD5 4TL.

P.C. Lack, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.

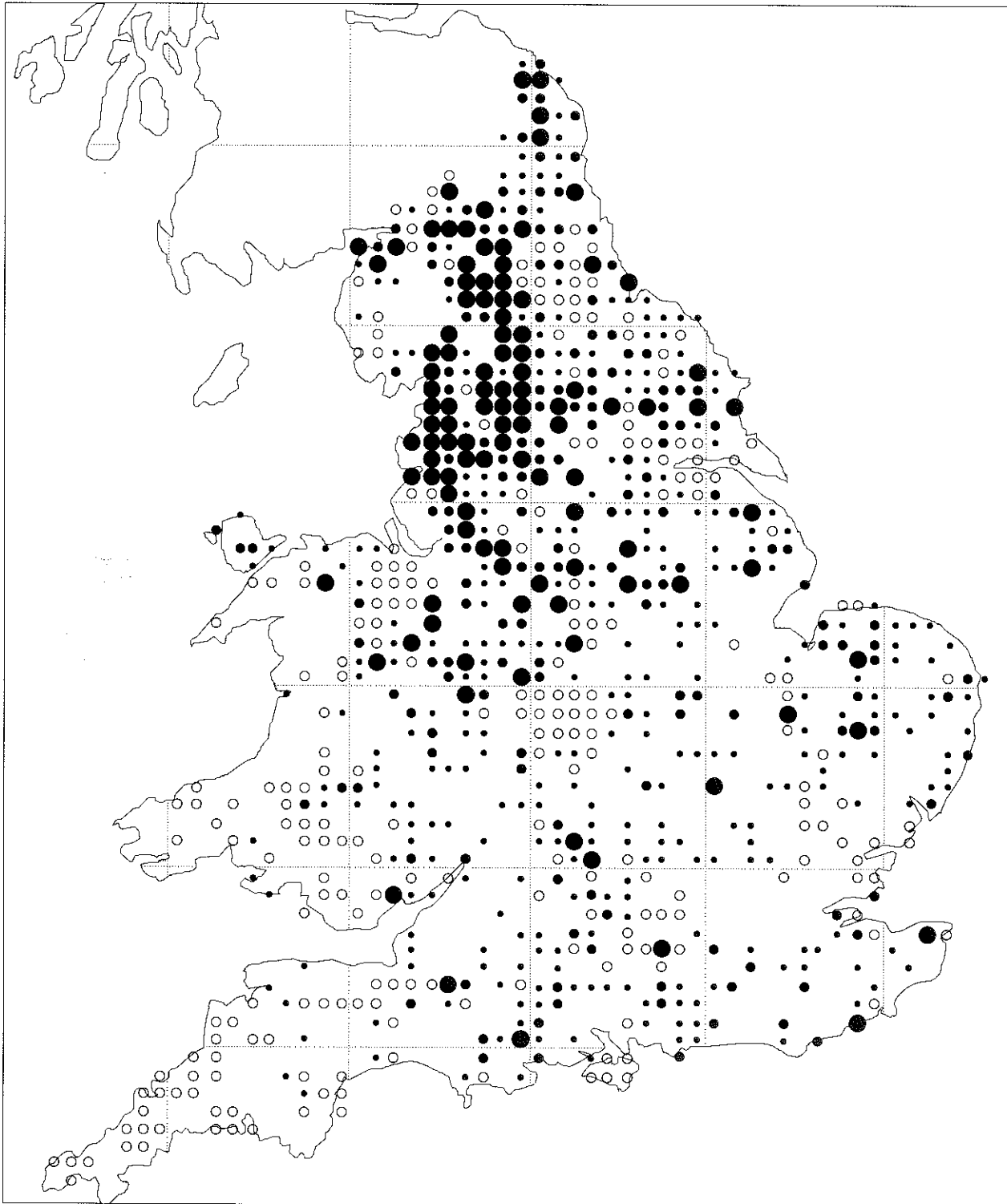
A survey of the numbers, distribution and habitat preferences of lapwings nesting in England and Wales was carried out by members of the British Trust for Ornithology in spring (April) 1987 (Figure 1). One tetrad (2 km x 2 km square) containing land in each 10 km square of the Ordnance Survey National Grid was randomly selected for survey, regardless of the amount of land actually in the tetrad. Observers were asked to count the number of pairs they found nesting in the tetrad and to record the farming or other habitat type the birds were in. The results were compared with the annual Agricultural Statistics compiled by the Ministry of Agriculture, Fisheries and Food (MAFF 1988) in nine regions, and to earlier surveys of the habitat preferences of the species

carried out in 1937 (Nicholson 1938) and 1960 (Lister 1964). In addition 27 sites surveyed in 1960 were re-surveyed in 1987. Of the 1,713 tetrads selected, 86% were surveyed, and 4,209 pairs of lapwings were found. This resulted in an estimate of 123,136 pairs for England and Wales, and the 95% confidence limits, derived from two bootstrap methods, were approximately 110,000 and 138,000. Table 1 shows how these nesting lapwings were distributed between the nine regions. On the 27 sites surveyed in 1960 and 1987 there was an overall decrease of 61% between the two surveys. Only three sites showed any increase and one of these is now managed as a nature reserve. These sites were, however, somewhat biased towards lowland farmland and did not

Table 1 Number of tetrads selected (86% were covered), percentage occupied by lapwings, number of pairs recorded and the estimated total numbers of lapwings in each of nine regions

Region	Total tetrads	% Tetrads occupied	Number recorded	Estimated total
North	171	61	987	29,335
Yorks/Humber	169	64	808	24,095
Northwest	79	75	753	21,135
East Midlands	160	41	352	9,428
East Anglia	140	41	245	6,495
West Midlands	132	54	335	9,960
Southeast	307	29	325	9,522
Southwest	291	21	181	5,718
Wales	264	20	223	7,448
Total	1,713	39	4,209	123,136

Figure 1 The distribution of nesting lapwings in England and Wales in 1987. The symbols represent numbers found in one tetrad in each 10 km square: small dot = 1-4 pairs recorded; medium dot = 5-10 pairs; large dot = more than 10 pairs; blank = the tetrad was visited but no birds were recorded; and an open circle = not surveyed.



sample adequately the area which is now the main stronghold of this species.

Overall, 96% of pairs were found in farmland. There was a marked avoidance of autumn-sown tillage crops and a marked preference for spring-sown tillage crops. Leys were the least preferred grass type and there was a preference for grazed rather than ungrazed fields. Within autumn tillage, fields with bare patches held more pairs than expected and those with tramlines held fewer, suggesting that areas of higher intensity farming are avoided. The preference for spring-sown tillage includes birds nesting on bare tilled land. It is interesting that birds will choose to nest in such fields despite the disruption caused by cultivations and sowing of the crop. This subject requires further study.

Leys are used primarily for silage or hay production rather than being grazed. Usually leys are fertilized fairly heavily and therefore the grass is often quite well grown by April, and taller than the lapwings prefer. There was also a greater preference for grass in regions in which there was only a small area of grass in comparison with the area of tillage, and there was a preference for individual tilled fields which were adjacent to grass fields. This suggests that the mixed farming regime of tillage and grass is preferred by lapwings, probably as a result of the birds preferring to take their chicks into grass for rearing (Galbraith 1988). A detailed study of the importance of mixed farming regimes would be helpful.

Since 1937 overall crop preferences have remained much the same although the preference index of lapwings for autumn-sown tillage has decreased and that for spring-sown has increased. There has been a substantial decline in the total number of breeding

lapwings, and in earlier surveys there was no sign of the concentration in northwest England. A detailed study in this area would be useful, especially to determine whether the large numbers are caused by the relation between tillage and grass or some aspect of the grassland management regime which is different to that in Wales and southwest England where numbers are very low. Between 1937 and 1960 there had been increases in central, south and southeast England, probably because the predominant 3 year cereal-ley rotation of the time provided ideal habitat.

A full report of this survey has been published in Shrubbs & Lack (1991).

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Breeding lapwings *Vanellus vanellus* on lowland grassland

M.G. O'Brien & K.W. Smith

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M.G. O'Brien, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.
Present address: Royal Society for the Protection of Birds, 17 Regent Terrace, Edinburgh, EH7 5BN.

K.W. Smith, Royal Society for the Protection of Birds, Sandy, Bedfordshire, SG19 2DL.

In 1982 a survey of lowland grassland in England and Wales was undertaken as a joint project between the British Trust for Ornithology, the Royal Society for the Protection of Birds and the Wader Study Group. The study was co-ordinated by the BTO. Surveys of 1,282 grassland sites resulted in a total of 6,721 pairs of breeding lapwings being recorded. Lapwings proved to be the most widespread breeding wader, recorded on 66% of all grassland sites surveyed. Concentrations occurred in Norfolk (1,082 pairs) and the North Kent Marshes (666 pairs). The number of pairs found in this survey represent only a fraction of the total number of breeding lapwings in England and Wales (Shrubb & Lack 1991).

A small number of lowland grassland sites have been monitored annually since 1984, as part of the Breeding Wader Monitoring Scheme. Results from this suggest that lapwing numbers had dropped to two thirds of their 1984 levels by 1988. The CBC index for lapwings on farmland shows a marked decline over the same time period. In 1989 the BTO co-ordinated a survey

of a random selection of the sites involved in the 1982 survey. The data were used to compare monitoring and sampling techniques. An analysis of the returns received so far indicates that there has been a significant decline in the number of breeding lapwings on lowland grassland, particularly in southern Britain. Table 1 indicates changes in numbers for each of five regions (from O'Brien & Smith, 1992).

Full details of this abstract have been published in O'Brien & Smith (1992).

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Table 1. Changes in lapwing numbers between 1982 and 1989 (taken from O'Brien & Smith 1992)

	East Anglia	Midlands	North	South	SW & Wales
Sites with no waders in 1982					
No. in 1982	0	0	0	0	0
No. in 1989	3	4	5	2	0
Non-reserves with waders in 1982					
No. of sites	45	43	25	39	40
No. of lapwings in 1982	241	243	229	853	233
No. of lapwings in 1989	192	124	204	236	105
Percent change	-20	<u>-49</u>	-11	<u>-72</u>	<u>-55</u>
Min CL	-47	<u>-67</u>	-31	-87	-77
Max CL	+27	-19	+15	-55	-23
Reserves					
No. of sites	16	1	10	3	2
No. of lapwings in 1982	652	14	124	162	9
No. of lapwings in 1989	280	20	208	103	5
Percent change	<u>-57</u>	+39	<u>+68</u>	-37	-44
Min CL	-70	-	+3	-	-
Max CL	-38	-	+84	-	-

Key:

No. of sites: the number of sample sites in the region where lapwings were recorded in either or both 1982 and 1989.

Percent change: percentage change in wader numbers between 1982 and 1989. A negative figure indicates a decrease in wader numbers.

CL: confidence limits, set at the 95% level, about the percentage change. Confidence limits were calculated using a bootstrap method (O'Brien & Smith 1992).

Significant changes (at $P < 0.05$) are underlined.

Factors affecting growth and survival of lapwing *Vanellus vanellus* chicks

A.J. Beintema & G.H. Visser

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A.J. Beintema, Institute for Forestry and Nature Research, Box 23, 6700 AA Wageningen, Netherlands.

G.H. Visser, Centre for Isotope Research, University of Groningen, Nijenborgh 4, 9747 AG Groningen, Netherlands.

Small lapwing chicks cannot maintain their own body temperature. As a consequence, when the ambient temperature is low, they have to be brooded by a parent at regular intervals. Since they search for their own food, they can only forage between brooding bouts. The length of such a foraging bout depends on the cooling rate of the chick, which is a function of age and the ambient temperature. Above a threshold temperature, the chicks do not need to be brooded at all. This threshold temperature drops with age, until a point is reached when the chick no longer needs to be brooded. In the lapwing, this takes about three weeks. During this period, especially in the first week, the chicks are vulnerable to adverse weather. Chicks seldom die of exposure, but they can lose so much feeding time through the need to be constantly brooded that too little time remains to find sufficient food to survive. To keep growing small chicks need to spend more than 25% of their time in feeding, which corresponds to about 5 hours per day in May-June. If less feeding time is available, they lose weight and eventually die of starvation. For small chicks, 'fine' weather can be defined as above 15 °C, during daylight and without rain (rain has a strong effect on temperature tolerance). In an average year the amount of 'fine' weather generally rises to above the required five hours in the first week of May. This corresponds to the beginning of the main hatching period, which has its peak in the second week of May. However, a substantial proportion of the lapwing chicks are born 'too early', and in some years

many of these perish. Later in spring, the small chicks have no such problems, and all grow well.

So, why do all lapwings not have their chicks later in the season? Adult lapwings feed on soil fauna, notably earthworms. Chicks, however, depend on surface fauna. They feed on beetles and flies and actively exploit cow-dung pats for dung beetles and various larvae. The insects in agricultural grassland reach their peak abundance in the first week of June, so later broods would seem to be ideal for the chicks. Nevertheless, the larger chicks seem to grow fastest very early in the season, and start to show reduced growth rates from around the middle of May. The fact that small chicks grow best late in the season, and the large ones early, presents an interesting dilemma. Why do larger chicks not grow well later in the season? A possible explanation is that the chick, when approaching fledging age, has to gradually change to soil fauna (worms). With its increased body size it is probable that it becomes unprofitable, maybe even impossible, to survive on insects alone, from an energetic point of view. Additionally, as spring progresses, worms tend to retreat to greater depths, where they may be beyond the reach of birds.

Apart from climate and hydrology, management also plays a role in the suitability of the habitat for the chicks. Earlier crop fertilization, mowing and grazing has led to an advance in the nesting season. More chicks may, therefore,

be confronted with bad weather in their first days. On the other hand, survivors will benefit from being older and stronger before autumn migration starts. Agricultural drainage helps the soil to dry out during spring, and consequently the worms may retreat to greater depths, making them out of reach of the chicks at an earlier stage. Heavy fertilization leads to a general decrease in the average body size of insects present in grassland, rendering them unprofitable as food for chicks at an earlier age.

Lapwing chick growth patterns differ considerably from those of the black-tailed

godwit *Limosa limosa*. Godwit chicks grow much faster, and become homoiothermic much earlier. From an energetic point of view, this is more 'expensive' in terms of food intake, but it requires less investment in brooding from the parents. The differences in growth strategies also have a zoogeographical aspect, the lapwing belonging to the plover family (Charadriidae), predominantly living in warm, often arid, conditions, while the godwit belongs to the sandpiper family (Scolopacidae), most of which live under rather cold conditions.

Factors determining the breeding success and distribution of lapwings *Vanellus vanellus* on marginal farmland in northern England

D. Baines

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D. Baines, The Game Conservancy Trust, Crubenmore Lodge, Newtonmore, Inverness-shire, PH20 1BE.

The breeding ecology of lapwings was studied on marginal hill farmland in the Eden Valley, Cumbria, and in Teesdale, Co. Durham, from 1985 to 1987. The area considered was the enclosed land or inbye fields immediately below the moor boundary. Fields were classified as either agriculturally improved or unimproved. Improved fields were characterized by having a lower water table and a drier soil as a result of land drainage. They were physically and vegetatively more homogeneous as a consequence of ploughing and reseeded, and subsequent applications of inorganic fertilizer had enhanced this uniformity by encouraging competitive grasses to the detriment of herbaceous species. The principal field types were pastures (67%), either rough (unimproved) or improved grazings; or meadows (29%) where hay (unimproved) or silage (improved) was grown.

Breeding waders were counted on adjacent unimproved and improved fields. Differences in these paired counts were assumed to be caused by the effects of agricultural improvement. Improvement resulted in the virtual disappearance of snipe *Gallinago gallinago*. In other species, improvement of pastures resulted in marked declines: 71% in lapwing, 81% in redshank and 82% in curlew. Meadow improvement resulted in less severe declines of 42%, 58% and 32% respectively.

Data on the breeding success of lapwings were collated to try to ascertain why lower densities are found on improved fields. Production on unimproved land (0.88 chicks fledged per pair,

n = 430) was sufficient to replace adult losses and so maintain numbers, whereas on improved land, production was too low (0.25 chicks fledged per pair, n = 161) to maintain existing breeding densities.

Three hypotheses to account for lower productivity on improved land were examined:

1. A reduction in invertebrate food or its availability.
2. A greater loss of clutches/chicks to agricultural machinery and/or trampling by stock.
3. Increased predation.

Invertebrates were sampled *in situ* using chemical expellents, extraction of animals from soil samples and pitfall trapping. Improved grasslands contained 52% more earthworms and 48% more beetles (excluding Carabidae) than unimproved fields, but had a 51% lower biomass of carabids and 36% fewer spiders. The density of tipulid larvae was similar in both field types, but fewer species were found on improved grassland.

Despite considerable differences in the invertebrate fauna between unimproved and improved fields, there was no discernible effect on either adult lapwings, which fed chiefly on earthworms and tipulid larvae, or chicks, which fed principally on beetles. Growth rates for chicks from unimproved and improved fields were compared for all three years, but only in one year was there a significant difference, with faster growth rates on unimproved fields.

Consequently, food availability to chicks was not considered to be limiting survival and was not a significant factor causing the differences in productivity described. However, data collected subsequently suggests that in very dry springs (1988 and 1989) chicks grow at a much slower rate, take longer to fledge and fledge at lower weights on drier drained fields.

The second hypothesis investigated was that on more intensively managed improved fields more clutches would be crushed by agricultural machinery or trampled by livestock. Data on hatching success was collated from a study of 637 clutches; 474 on unimproved fields and 193 on adjacent improved fields. Clutch loss was only appreciable on silage fields, where 22% of clutches were squashed by agricultural rollers, significantly more than on any other grassland type. On silage fields, this loss, combined with fewer clutches being replaced, accounted for the low breeding success. Only 2% of all clutches were trampled by livestock. There was no evidence of chicks being killed by either means once they had left the nest. Consequently, more intensive grassland management directly affected lapwing productivity on silage fields, but not on improved grazings.

The third hypothesis was that grassland improvement resulted in reduced nest crypticity and hence increased clutch predation. Over the three years, 76% of lapwing clutches on improved pastures were taken by predators compared to only 47% on unimproved pastures. The proportion taken on meadows was around 50% with no difference between unimproved and improved fields. Observed egg predators were carrion crows *Corvus corone* and black-headed gulls *Larus ridibundus*. It was concluded that increased nest predation on improved pastures resulted from reduced nest crypticity following reseeding and fertilizer applications which in turn reduced the diversity

and structure of the surrounding vegetation. Survival of chicks up to 10 days old was significantly higher on unimproved fields than on equivalent improved ones and, considering similar levels of food availability, it is likely that this too is attributable to higher rates of predation. Thus, increased predation chiefly accounted for the lower breeding success on improved pastures relative to unimproved.

The predation hypothesis was tested using dummy nests, with black-headed gulls eggs being used to simulate lapwing clutches. After seven days, more than twice as many eggs had been taken from improved fields than from unimproved. Predation rates were also considerably higher in fields where no lapwings were nesting. If differences in productivity cause the differences in density found between unimproved and improved fields, then there must be either considerable philopatry or, alternatively, adults selecting areas to breed must select unimproved areas. Limited evidence suggests that considerable philopatry occurs and that chicks return to the same field rather than merely the same area.

Despite insufficient productivity on improved fields to maintain existing populations, considerable numbers of birds are still found there. Surplus recruits must be available from unimproved areas in good breeding years to top up numbers on improved fields. Therefore, the scale of agricultural mosaic must be critical in determining the distribution and density of breeding lapwings, with sufficient high productivity on 'source' fields counterbalancing the low productivity fields or 'sink' fields. These factors will be investigated in detail within the next three years, when differences in lapwing breeding success, philopatry and mortality will be investigated between fields, between study areas and between regions.

Effects of predation and agriculture on a lapwing *Vanellus vanellus* population in southern England

B. Pearson & C. Stoate

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B. Pearson, Institute of Terrestrial Ecology, Furzebrook Research Station, Wareham, Dorset, BH20 5AS.

C. Stoate, The Game Conservancy Trust, Fordingbridge, Hampshire, SP16 1EF.

The observed decline in lapwing numbers, particularly in the south of England, stimulated the present investigation into the effects of predation and agriculture on breeding success in this species. An experimental regime on Salisbury Plain was used. This had been established by the Game Conservancy Trust to study the effects of predation on breeding success in the grey partridge *Perdix perdix*. The study areas were established as follows: Area A, where certain predators were controlled for the first two years, and Area B, where predators were uncontrolled. The regime was switched after the second year to control for contingent variables. Four years of the study have now been completed. A significant decrease in predation rates on lapwing eggs was observed consistent with expected differences in predation pressure established by the experiment. The difference was a 61% decrease in nests predated in the 'predator free' areas. Predator control also benefited the partridge population resulting in gains of a larger order. Thus predator management to protect game would appear to considerably improve partridge survival and to carry with it the bonus of increasing breeding success in the lapwing, though to a lesser degree.

Although cereal fields were adopted for nesting areas, lapwing chicks moved into adjacent water meadows soon after hatching. Chicks were caught and ringed in these feeding areas in each of the four years on Area A. Although this was not designed to test the impact of predator control on chick survival, fewer chicks were

seen and ringed on Area A in the period when predator control was absent. However, chick survival based on the number of newly hatched broods seen showed no significant change over the period. It is possible that chicks are most vulnerable to predation when travelling from the nest site to feeding areas, a distance of 450 metres in many cases.

The effects of agricultural practice on nest survival could also be quantified for these study areas. Most of the birds bred on arable land. Much of the arable land in the experimental area is sown for winter cereals. Mild winters cause prolonged stem elongation and fields become unsuitable for breeding lapwings. Thus a lot of potential breeding habitat is no longer available. During cold winters, crop growth is slower and the fields are usually still in a suitable condition for lapwing breeding in the spring. However, autumn sowing of the crop brings forward other farming practices, namely rolling and harrowing. On average, these processes occur a week before the peak hatching time on Salisbury Plain where 45% of nests were found to be potentially at risk. Only 15% of 'at risk' nests were actually lost. This low level of actual loss was primarily through the vigilance of tractor drivers. The precise timing of rolling and harrowing are not usually agronomically critical. If these could be delayed by 10 to 14 days, significantly more nests would survive. Chicks are at less risk than eggs, particularly where the arable land adjoins pasture. Whatever the winter conditions, the crop has usually

grown too high for chicks to forage in by the peak hatching time.

The trend, particularly over the last decade, of increasing the acreage of winter wheat, is probably the single most significant cause of the decline of the lapwing in the south of England. Predator control is extremely costly and consequently as a management measure for the benefit of a non-game species alone is unlikely to be applied. Predator control is also controversial, particularly in the context of conservation of bird species other than game birds, for ethical and aesthetic reasons. In terms of cost effectiveness, vigilance of tractor drivers

and/or a delay in rolling and harrowing of fields would appear to be the practices to encourage.

It is concluded that the most cost-effective way of conserving the lapwing population, within the present agronomic constraints, is through minor adjustments in the agricultural routine associated with the production of winter cereals. It is expected that, should these agronomic constraints change in a manner favourable to the sowing of spring cereals, this will benefit the lapwing considerably. The sowing of spring cereals with the inclusion of some pasture in arable systems would improve conditions for lapwing survival in southern England.

Trends in habitat selection by lapwings *Vanellus vanellus* during the non-breeding season

T.P. Milsom

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T.P. Milsom, Ministry of Agriculture, Fisheries and Food, Central Science Laboratory, Tangleway Place, Worplesdon, Surrey, GU3 3LQ.

Lapwing numbers, distribution and habitat selection during the species' non-breeding season (July-March) were studied on part (27,500 ha) of the North Downs in Hampshire, over five winters: 1980-85. Within the North Downs study area, lapwing flocks occupied eight discrete ranges, each approximately 5 km distant from its nearest neighbour. As the main aim of the study was to investigate the use that lapwings made of aerodromes in relation to the hazard that the species presents to aviation safety, most work was done in a flock range that was centred on the aerodrome at Lasham (Milsom & Rochard 1987).

Lapwings occupied the Lasham flock range throughout the year (Milsom & Rochard 1987; Milsom, Holditch & Rochard 1985). Their numbers remained low (< 50) during the breeding season but increased from late June onwards to peak in August (300-700 birds). Numbers then fell to a low in early September, recovered quickly thereafter and continued to increase to a second much larger peak in November or December (800 in 1980, rising to 1600 in 1985). Wintering birds departed in February and March. Severe cold caused the flock range to be deserted temporarily.

Overall, lapwings preferred grassland as a feeding habitat, but selected arable habitats during August and September. The pattern of habitat selection by birds resting during daylight or twilight was similar, except that they also preferred the runways and aircraft manoeuvring areas on the aerodrome from July to March. In addition the birds showed a broad preference for habitats where the ground vegetation was short

or absent altogether. Thus their use of grassland was correlated with the factors that regulated the height of the sward: mowing, cropping and grazing. Grassland that was mown short throughout the growing season was used for the longest period, whereas meadows were only visited after hay/silage cropping, and again after the sward had been flattened by snow and frost. Pastures were only used where the sward had been grazed. On arable land, maturing crops which were tall and dense were never visited, stubbles were generally avoided, and burnt stubble, newly emerging crops and, especially, ploughed land were preferred. Aerodrome runways and aircraft manoeuvring areas, where ground vegetation was very sparse, were used intensively throughout the non-breeding season (Milsom, Holditch & Rochard 1985; Milsom 1990).

Over and above the broad trends identified above, there was a marked seasonal variation in the habitat selection strategy adopted by feeding lapwings. This comprised three phases. The first lasted from July to September, during which the birds used a large number of habitats (mostly arable) for short periods. Up to four habitats were preferred in any month and preferences changed between months. A very stable phase lasted from October to January, when the birds showed a very strong preference for the frequently mown grassland on the aerodrome. A second dynamic phase occurred in February and March, when many birds switched to pasture and then to meadow grassland. There was some evidence to suggest that the dynamic phases coincided with periods

of poor or fluctuating prey availability (Milsom 1990).

When the pattern of habitat selection was reassessed on a larger scale, over the North Downs study area as a whole, significant differences between flock ranges were discovered. In June and July, most lapwings were restricted to non-arable habitats such as water margins, cropped hay meadows and the aerodrome at Lasham because most arable land was unavailable as it was covered by tall and dense crops. During this period, the aerodrome at Lasham acted as a refuge for moulting flocks and up to 50% of the North Downs population was to be found there. However, once the birds had moved onto arable land after harvesting and ploughing had commenced, the pattern of habitat selection by lapwings at Lasham differed markedly from those in neighbouring flock ranges, most notably in the timing of the switch from arable to grassland (Milsom 1990). This occurred in early October in Lasham but very much later elsewhere (December-February). In this respect, the birds' behaviour in the flock ranges away from Lasham was similar to that reported from West Sussex (Shrubb 1988) and northern France (Balança 1984). There were corresponding differences in the population trends in each flock range. At Lasham, numbers rose following the switch from arable to grassland, whereas they declined in all the neighbouring flock ranges where arable remained the preferred habitat (Milsom & Rochard 1987). This change in distribution resulted in a rise in the proportion of the North Downs population using the Lasham flock range, from 11% of the population to 38%, between October and December. The Lasham flock range continued to support the largest proportion of the population (30 to 35%) through until late February. Despite the considerable variation in the timing of the switch from arable to grassland, the birds' preference for the frequently mown grassland on Lasham aerodrome was so strong that grassland (all management regimes combined) became the preferred habitat on the North Downs as a whole (Milsom, Holditch & Rochard 1985).

This study raises three main points that are relevant to the assessment of habitat requirements of lapwings and the species' management during the non-breeding season:

1. Different habitats are important to lapwings at different seasons: non-arable habitats act as a refuge during the summer, especially for resting flocks of moulting birds; arable, especially plough, is the preferred habitat during autumn; and grassland is the preferred habitat during the winter.
2. The management of grassland can have a major effect upon its attractiveness to lapwings. Large areas of semi-permanent grassland that are mown short throughout the growing season (as on many aerodromes) can support large feeding flocks of lapwings throughout most of the autumn and winter.
3. The outcome of any study of habitat selection by lapwings during the non-breeding season may well be determined by the scale at which it is conducted.

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The relationship of lapwing *Vanellus vanellus* numbers and feeding rates to earthworm numbers in arable and pasture fields in autumn and winter

A. Village & N.J. Westwood

Village, A., & Westwood, N.J. 1994. The relationship of lapwing *Vanellus vanellus* numbers and feeding rates to earthworm numbers in arable and pasture fields in autumn and winter. In: *The ecology and conservation of lapwings Vanellus vanellus*, ed. by G.M. Tucker, S.M. Davies and R.J. Fuller, 47-48. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 9.)

A. Village, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, PE17 2LS.
Present address: 18 The Avenue, Cliftonville, Northampton, NN1 5BT.

N.J. Westwood, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, PE17 2LS.

The aim of this study was to investigate the relationship between plovers (i.e. lapwings *Vanellus vanellus* and golden plovers *Pluvialis apricaria*) and earthworms, particularly in arable fields. There were two study areas: the mixed farmland area covered about 25 km² of the Welland Valley and was cropped for wheat, barley and oilseed rape, with permanent pastures along the valley bottom. The arable farmland area was 20 km² of Cambridgeshire fen, intensively farmed for wheat, sugar-beet and potatoes, with virtually no pasture or ley-grass.

The two main aims of the work were to monitor at regular intervals the total number of birds using the fields in each study area, and to measure plover feeding rates and earthworm numbers in particular fields when they were used by feeding birds. Plover feeding rates were recorded with an automatic data logger, and earthworm numbers by formalin extraction at eight 50 cm x 50 cm quadrats per field. This was done on 22 occasions in 12 different fields in the mixed area between 3 October 1988 and 20 January 1989.

Pasture fields generally had higher earthworm numbers than cereal fields. Lapwings avoided pastures in early autumn, possibly because the soil was dry and no earthworms were near the surface. In early autumn, earthworms seemed to become available to plovers only when fields

were tilled, and plovers preferred recently tilled fields at that time of year. The effects of tillage seemed to be transitory, however, and fields were often not used for more than three days after they were first cultivated. No sampling for earthworms was undertaken before October and therefore it is not possible to determine whether lapwings avoided pastures in early autumn because the availability of earthworms was low or because it was much higher in fields that were being tilled. An increased preference for pastures by lapwings in December coincided with a decline in total lapwing numbers in the mixed farmland area. It seemed that much of the autumn lapwing population was exploiting a transitory food source on tilled land, and that the amount of pasture in the area was insufficient to maintain this population throughout the winter.

Pastures had higher earthworm populations than cereal fields, but this did not necessarily result in either faster lapwing feeding rates in pastures, or in higher lapwing densities over the season as a whole. Within cereal fields, lapwings had higher feeding rates (Figure 1) and higher densities over winter (Figure 2) in those fields that had higher earthworm numbers when sampled. In the few pastures studied, lapwings had a much lower feeding rate than expected from the high earthworm numbers. This may reflect the difficulty lapwings have in seeing

earthworms among vegetation, compared with the almost bare ground of young cereal fields.

Cereal fields seemed to provide a temporary, but easily exploited, source of food for plovers in early autumn. The decline in use of cereals later in winter was partly because fields were no longer being tilled, but it may also have reflected a change in earthworm availability as the new crop grew. Lapwings rarely used cereal fields once the newly established crop was more than

about 75 mm high. Whether this was because of the increasing vegetation cover, or because earthworms were no longer near the surface, requires more study. In addition, the pastures become increasingly moist through the autumn and by the onset of winter, earthworms may have become readily available there, making pastures more attractive irrespective of any changes to cereal fields.

Figure 1. Rate of capture of earthworms by lapwings in relation to earthworm numbers from formalin sampling in cereal fields (O) $r = 0.96$, $df = 7$, $p < 0.001$ and pastures (●) in mixed farmland 1988/9. Each point is the mean for several lapwings followed in a particular field (y) and the mean number of earthworms expelled from eight quadrats (x).

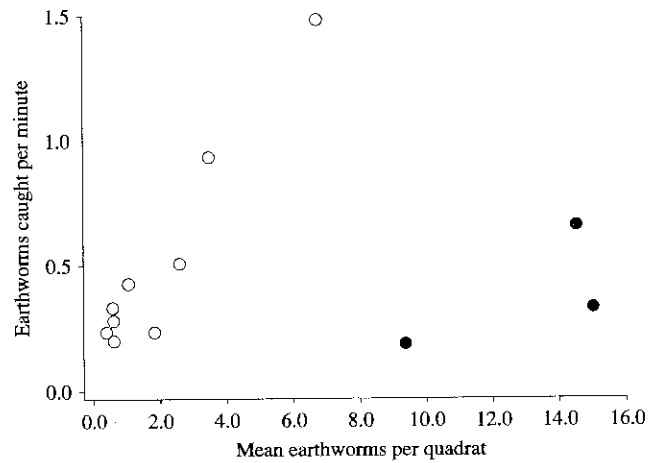
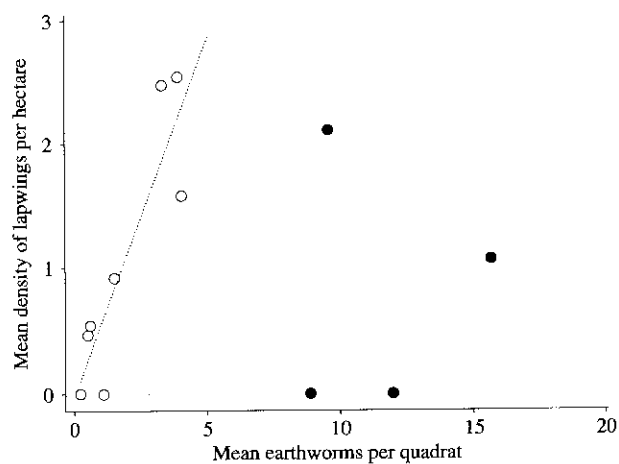


Figure 2. Average lapwing density in fields during autumn and winter in relation to earthworm numbers in cereal fields (O) and pastures (●) in mixed farmland, 1988/9. The line is the linear regression fitted to cereals only: $r = 0.89$, $df = 6$, $p < 0.001$.



The effects of agriculture on the nesting of farmland lapwings *Vanellus vanellus* in England and Wales

M. Shrubbs

Shrubbs, M. 1994. The effects of agriculture on the nesting of farmland lapwings *Vanellus vanellus* in England and Wales. In: *The ecology and conservation of lapwings Vanellus vanellus*, ed. by G.M. Tucker, S.M. Davies and R.J. Fuller, 49-51. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 9.)

M. Shrubbs, Hill Crest, Llanwrtyd Wells, Powys, LD5 4TL.

The British Trust for Ornithology's nest record cards for lapwings on farmland in England and Wales were analysed up to 1985. Effort was concentrated on the period after 1962 to enable the results to be examined against the Common Birds Census index. Some analyses were, however, taken from 1940 for longer comparisons over time.

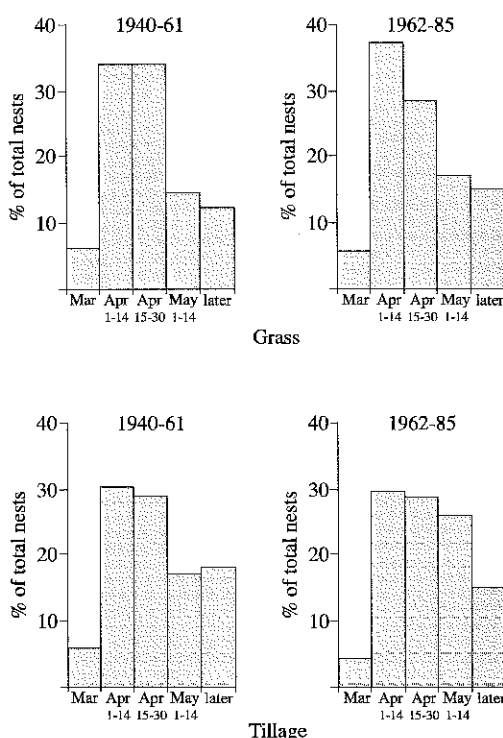
For analysis the cards were classified under the following agricultural habitat categories - upland rough grass, upland improved grass, lowland rough grass, lowland improved grass, autumn cereals, spring cereals, 'cereals', bare plough, bare tilth, other spring crops. The analysis was limited to nesting performance until broods hatched because assessments of fledging success of lapwings from nest record cards are unreliable.

The main results were as follows:

1. Significant changes in the time of nesting in 1962-85 compared to 1940-61 were found (Figure 1). Lapwings apparently now nest earlier in grass but later in tillage. However, the causes of nest loss (see below) suggest that these differences actually reflect differences in nest replacement. This is now more difficult in grass, so fewer later nests are recorded. Increased nest losses in tillage (caused by climate-related changes in the timing of cultivation) are more readily replaced, producing an extended laying period.
2. Despite small, but statistically significant, differences between grass and tillage and

between different grass habitats, little important change in clutch size has occurred over a 45 year period.

Figure 1. The percentage of completed lapwing clutches recorded in different periods of the nesting season in grass and in tillage in England and Wales for 1940 to 1961 and 1962 to 1985. The differences shown between the two periods in both habitat groups are statistically significant: grass, $\chi^2 = 13.74$, $df = 4$, $p < 0.01$; tillage, $\chi^2 = 13.95$, $df = 4$, $p < 0.01$.



3. In contrast, brood size at hatching has declined significantly (Figure 2). This results from rising total nest losses. In successful nests the production of hatchlings has not varied significantly over time nor between habitats. Nest losses have risen in all habitats, and in cereals, upland and lowland rough grass and upland improved grass this rise is strongly significant. Despite more losses, spring cereals remain

the most successful nesting habitat, largely because losses are readily replaced. The percentage of nests producing at least one chick in each habitat was: upland rough grass 49%, upland improved grass 40%, lowland rough grass 56%, lowland improved grass 58%, cereals 71%, bare plough 43%, bare tilth 69% and other spring crops 57%.

Figure 2. Annual trends in mean brood size at hatching of lapwings nesting in grassland (—) and tillage (----) in England and Wales from 1962 to 1985. The horizontal lines show the overall means for each habitat group. Both trends are significant: grass, $r_s = -0.54$, $P < 0.01$; tillage, $r_s = -0.45$, $P < 0.05$.

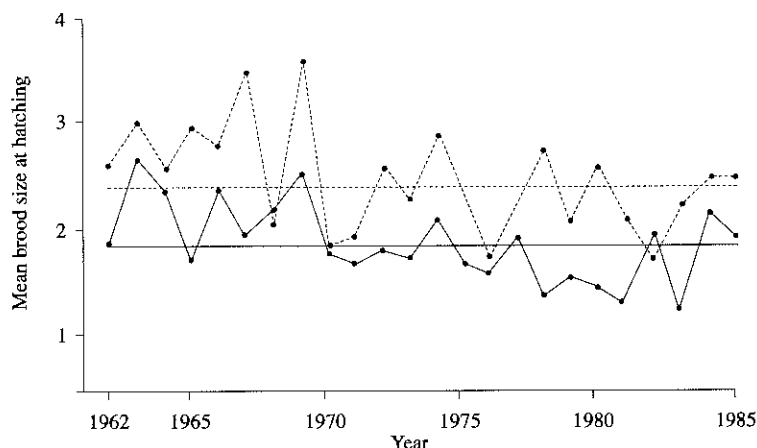
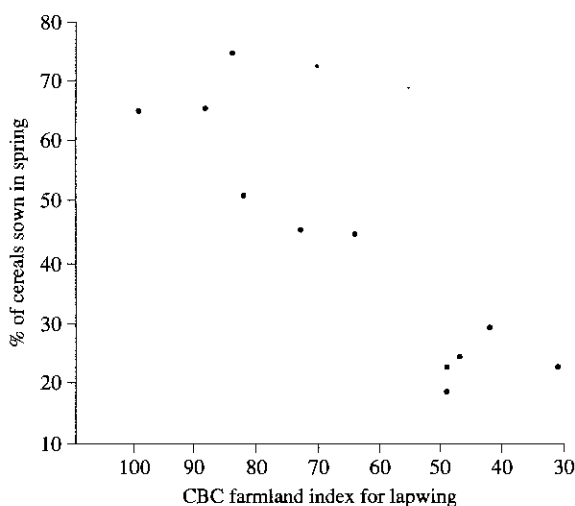


Figure 3. The CBC index for lapwings in the primarily cereal-growing counties of England and Wales compared to the percentage of spring cereals there during 1962 to 1983. The 11 years shown are those for which a good estimate of the area of spring cereals could be made from the MAFF statistics. The correlation is highly significant: $r_s = +0.88$, $P < 0.01$.



4. The main causes of nest losses were desertion (8% of total nests), predation (17%) and agriculture (cultivation and farm stock) (19%). Compared to before 1962, predation declined, as did desertion in tillage, but desertions in grass doubled and are now correlated significantly with more cattle. Losses to agriculture increased by c. 60% or, if stock-related desertions are also included, losses to agriculture more than doubled. Outside farmland 72% (cf. 54% within farmland) of lapwing nests were successful. In both habitat types they lost c. 25% of nests to desertion, predation or causes such as flooding but in habitats outside farmland only 3% of nests were lost to 'industrial' causes comparable to agriculture.

5. The mean brood size at hatching in each habitat was: upland rough grass 1.67, upland improved grass 1.38, lowland rough grass 2.17, lowland improved grass 2.03, spring cereals 2.55, bare plough 1.94, bare tilth 2.96 and other spring crops 2.10. The overall means were grass 1.84 and tillage 2.40. Productivity has been studied in detail in central Scotland by Galbraith (1988). His results suggest the mean brood size at hatching calculated from nest record cards needs to be c. 2.20 young for populations to be self-supporting. Grassland populations in England and Wales do not meet this criterion and upland grass, which supports most grassland lapwings (Shrubb & Lack 1991), is the least productive. In tillage, nesting success remains satisfactory but fledging success is controlled by the availability of nearby grassland for rearing chicks (Galbraith 1988, Shrubb & Lack 1991). Few arable areas now provide these conditions because of the loss of two-thirds of spring-tilled fields. In cereal counties this correlates very closely with the decline in lapwings (Figure 3).

Clearly farmed grassland is now unsatisfactory nesting habitat for lapwings. But Galbraith (1988) showed that chicks strongly prefer intensively grazed grass for feeding. This anomaly may hold the key to conserving lapwings in farmland. Creating grasslands in which they can nest sufficiently successfully involves too great a concession by farmers to be economically practical. By far the most successful nesting lapwings are in spring cereals but their final production of young is limited by lack of nearby grass fields to rear their chicks.

The solution may be to encourage more spring cereals and to consider their relationship with grass fields. Economically, spring cereals may produce lower yields than autumn cereals (particularly in a year like 1989) but have advantages in quality and reduced inputs (mainly nitrogen and pesticides) which will increasingly counter-balance lower yields. It is unnecessary to press for a total reversal of the trend to autumn cereals. What is required is a significant increase in spring crops, coupled with careful consideration of their distribution in relation to grass. The latter is a matter for advice on the farm. Lapwings must be conserved on farmland.

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The effects of farm practices on lapwings *Vanellus vanellus* and their food resources in winter

G.M. Tucker

Tucker, G.M. 1994. The effects of farm practices on lapwings *Vanellus vanellus* and their food resources in winter. In: *The ecology and conservation of lapwings Vanellus vanellus*, ed. by G.M. Tucker, S.M. Davies and R.J. Fuller, 52-53. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 9.)

G.M. Tucker, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.
Present address: BirdLife International, Wellbrook Court, Girton Road, Cambridge, CB3 0NA.

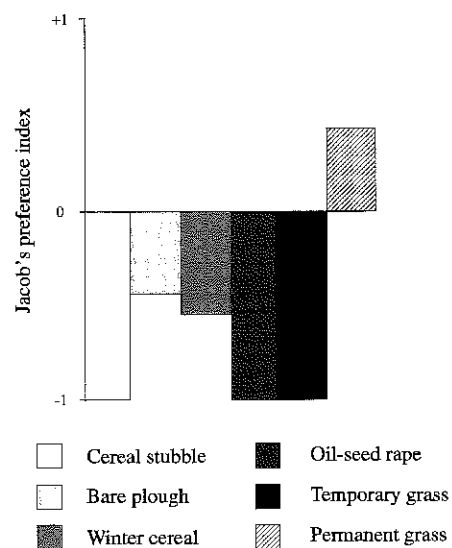
During the winter of 1987/88 a study of the use of fields by birds feeding on invertebrates was carried out in an area of mixed lowland farmland in the Vale of Aylesbury. This study aimed to establish the effects of farming practices on field-use by invertebrate-feeding birds and on the density of invertebrate food resources. Whole field counts of birds were made three times per month, on 151 fields, from November to the end of February. Detailed habitat and farming practice information was collected for each field. Invertebrate densities were also estimated from a sub-set of 80 fields. Fifteen soil cores (12 cm diameter, 5 cm depth) were taken from each sampled field. The invertebrates were extracted by a combination of mechanical soil washing and flotation.

Field preferences by feeding lapwings are shown in Figure 1. Permanent grass fields were the most strongly selected feeding habitats. Permanent grass fields supported significantly higher densities of lapwings than temporary grass, cereal stubble, bare plough, winter cereal and oil-seed rape fields. These results can be at least partly explained by the availability of food resources. Permanent grass fields held higher biomass densities of both earthworms and other soil invertebrates than all other field types.

Although the preference for permanent grass fields remained through the winter, the use of bare plough and winter cereal fields declined significantly during the study period (Figure 2). The cause of this is unknown. However, it may be related to either the effects of soil structure and insulation on invertebrate availability or to

changes in foraging efficiency as a result of vegetation growth.

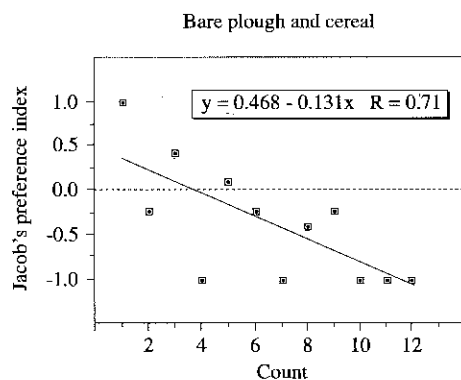
Figure 1. Mean field use preference indices (Jacobs 1974) for lapwings in the Vale of Aylesbury during the winter of 1987/88. Index values are based on frequency of lapwing occurrences in each field.



Further detailed analyses of the effects of farming practices on field use by lapwings were carried out by logistical modelling. This revealed that for grass fields, the likelihood of fields being used by lapwings was positively related to the frequency of farmyard manure application over the previous five years, the frequency of cattle presence and the size of the

field. The frequency of sheep presence in each field was negatively associated with the likelihood of use by lapwings. These results cannot be wholly explained by the effects of farming practices on invertebrate density. Invertebrate density was not positively associated with farmyard manure input. Instead, both earthworm and beetle density were positively related to the age of the grass. However, earthworm density was negatively related to sheep presence and this may explain the negative relationship with lapwing occurrence. It is possible that this relationship is noted because sheep are restricted to poor land and this in turn supports lower invertebrate densities.

Figure 2. Changes in use of bare plough and winter cereal fields by lapwings in the Vale of Aylesbury during the winter of 1987/88. Count refers to the order of each count within a sequence of 12, taken between 1 November 1987 and 28 February 1988. Each count is the combined data from bird counts made over several days.



Lapwing occurrence on bare plough, winter cereal and oil-seed rape fields was also positively associated with farmyard manure input. In this case, this was clearly related to invertebrate density, as farmyard manure input was positively associated with earthworm density on arable fields. The period of continuous annual cultivation was also negatively associated with earthworm density.

This work indicates the importance of old, fertile grass to lapwings. However, further research is needed, especially as the effects of winter mortality on lapwing population dynamics and whether winter populations are limited by suitable habitat are unknown. We also need further information on the effects of pesticides (particularly molluscicides), cultivation methods and grazing on food availability.

On the basis of current information, practical conservation measures for winter lapwing populations should target effort to traditional lapwing wintering sites and include:

1. The maintenance of large, old, fertile pastures.
2. Frequent use of farmyard manure on grass and cereals.
3. Use of grass leys as break-crops.

These measures could have real practical benefits and would incur little additional cost to farmers. Indeed, the use of organic manure and break-crops are compatible with good farming practice and may produce long-term benefits in soil structure and fertility.

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Winter distribution and habitat use by lapwings *Vanellus vanellus* in the Vale of Aylesbury

J.S. Kirby & R.J. Fuller

Kirby, J.S., & Fuller, R.J. 1994. Winter distribution and habitat use by lapwings *Vanellus vanellus* in the Vale of Aylesbury. In: *The ecology and conservation of lapwings Vanellus vanellus*, ed. by G.M. Tucker, S.M. Davies and R.J. Fuller, 54-55. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 9.)

*J.S. Kirby, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.
Present Address: The Wildfowl and Wetlands Trust, Slimbridge, Gloucester, GL2 7BT.*

R.J. Fuller, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.

The distribution of lapwings in winter (October to March) has been studied in the Vale of Aylesbury (Buckinghamshire, Hertfordshire and Oxfordshire) since the mid-1970s and the distribution across habitats has been recorded in detail at three sites for up to nine consecutive winters. The landscape of the Vale is predominantly one of mixed agriculture, with a large proportion of autumn-sown cereals and some grazing of livestock on both permanent and reseeded pastures and leys. At the three intensive study sites, during most winters, stubbles were only available to the birds in October, whilst other farmland habitats, particularly grassland and cereals, stubbles were available throughout the winter. The proportion of grassland at these three sites ranged from 30% to 70%.

Overall distribution

The distribution of wintering lapwings in the Vale of Aylesbury was highly clumped with certain areas holding more or less consistent concentrations of birds. A large proportion of fields in the Vale never, or rarely, held lapwings. Thus, discrete flock ranges were evident, each encompassing several feeding sites. The main feeding sites within flock ranges sometimes changed between consecutive winters, though particular areas were strongly favoured over several winters. In very cold weather, but when there was insufficient snow to force birds to emigrate, lapwings dispersed widely and feeding birds occurred in a very large

number of fields, both within and outside the flock range. The numbers in each field were, however, small.

During periods of presumed night-time feeding, virtually all the lapwings from within the flock range congregated into day-time roosts, sometimes situated several kilometres from the feeding grounds. Day roosts were frequently occupied for a period of several days and then abandoned when day time feeding was resumed. A day roost could be used for several consecutive winters but could then be abandoned suddenly and a new roost selected; two examples involved shifts of some 5 km. Usually the birds congregated in a single roost, occasionally at two. Shifts in both feeding and day roosting sites were not associated with changes in cropping. During periods of diurnal feeding, birds often roosted close to the feeding sites.

In the absence of prolonged snow cover, numbers in most flock ranges usually peaked in midwinter. However, the pattern of seasonal variation in numbers sometimes differed between flock ranges within the same winter. Peak numbers occurred earlier in some ranges than others, and some ranges occasionally showed temporarily reduced numbers. Nothing is known about the movements of individual birds between flock ranges, nor of any long-term fidelity to flock ranges.

Roosting habitats

At all three study sites, tilled land was strongly preferred for roosting. The birds made heavy use of ploughed land or recently sown cereals when available. Roosting on grassland was uncommon, but occurred most frequently in January and February. This may have been because much of the tilled land supported fairly tall and dense crops of cereals by this time, which are probably less suitable for roosting than young cereal crops or bare ground. There was evidence of a higher proportion of lapwings roosting on grassland at the site where this habitat was most prevalent. Day roosts were nearly always on exceptionally large winter cereal fields.

Feeding habitats

There was considerable variation in the selection of feeding habitat between flock ranges, particularly in the extent to which grass was used, but some similarities were evident. In early winter, birds often selected tilled fields for feeding, but this was usually followed by a switch to feeding on grassland. The timing of this switch varied between winters and between flock ranges within the same winter. Data for eight winters from one site showed that in some winters grass was strongly preferred as early as October, but in other winters large numbers of birds remained on cereals in November. However, in December and January there was an overwhelming preference for grassland in nearly all winters. In February and March, lapwings showed evidence of a return to feeding on cereal crops in some years. There was evidence that preference for grassland has increased over the study period in the Vale of Aylesbury.

Grassland appears to be the preferred feeding habitat during periods of cold weather. A clear illustration of this was given by lapwings which were feeding on tilled fields at one site and responded to a cold spell in November by switching their feeding effort to grassland. They returned to tilled habitats when conditions had ameliorated. The use of grassland for feeding also varied during the day with greater usage in the morning, when temperatures were generally low, than around midday and particularly late afternoon.

Several factors may exert a combined influence on the seasonal and diurnal patterns of habitat selection described above. Firstly, there may be a gradual decrease in the attractiveness of tilled fields through the winter as the amount of bare ground declines and as the vegetation of cereal crops becomes too long for lapwings to feed efficiently. Secondly, there could be a reduction in the amount of invertebrate food available to lapwings in tilled habitats as the winter progresses. Third, there may be an increase in food availability on grassland, perhaps as the water content of grassland soils increases and worms are forced closer to the surface. Fourthly, the birds appear to have different diets on cereal and grass fields - fewer worms seem to be eaten on cereals which reflects the differences in the invertebrate faunas of the two types of field (G.M. Tucker pers. comm.). Finally, low temperatures may result in a greater reduction in invertebrate availability on tilled habitats than on grassland. Such an effect could arise if the vegetation of cereal crops offers less insulation, causing invertebrates to become less active or to move down the soil profile, hence offering fewer cues to the birds.

Ecology of curlews *Numenius arquata* and lapwings *Vanellus vanellus* on farmland

Å. Berg.

Berg, Å. 1994. Ecology of curlews *Numenius arquata* and lapwings *Vanellus vanellus* on farmland. In: *The ecology and conservation of lapwings Vanellus vanellus*.

This abstract is a copy of the summary of a thesis (Berg 1991) and is reproduced here with the kind permission of the author.

Å. Berg, Department of Wildlife Ecology, The Swedish University of Agricultural Sciences, Box 7002, S-750 07, Uppsala, Sweden.

This thesis deals with the ecology of curlews *Numenius arquata* and lapwings *Vanellus vanellus* on different farmland habitats in central Sweden. Both species have declined in numbers since the 1940s, when modernisation of farming started. Lapwings and curlews were found in higher densities in farmland with traditional farming than in modern arable farmland. Curlews preferred territories close to rivers with a high proportion of grassland, where Lumbricids were most available in the pre-breeding period. There were more curlew territories in large grassland patches than in small ones and unoccupied grassland patches, were more isolated than occupied ones. Lapwings preferred sites close to, or on, flooded fields, which were the most important foraging habitat. The distribution of foraging habitats seemed to be important for determining the densities of these species in farmland.

Reproductive success differed between habitats. Curlews preferred to nest in grasslands and in fallow fields, where reproductive success was higher than in tillage, due to less destruction of nests during spring farming. Lapwings preferred to nest in tillage, despite most nests being destroyed during spring farming. Nevertheless, the total hatching success of lapwings in this habitat was higher than in other habitats, due to the high proportion of replacement clutches and their high hatching success. Lapwings avoided predation by

breeding in aggregations and far from perches for avian predators, while curlews selected sites far from forest edges, where chick survival was highest. Experiments with artificial wader nests showed that differences in predation rates might explain variation in the density of waders on bogs in different regions of Sweden.

The production of curlew fledglings on farmland was too low to maintain stable populations (sink habitat), and the increase of populations in recent years is probably an effect of immigration from bogs (source habitat), where reproductive success was higher. There were no trends in the studied lapwing populations; they fluctuated between years, which probably was an effect of differences in spring flooding between years. Lapwings were also less philopatric than curlews, probably an adaptation to fluctuating habitat resources. Changes in land use and habitat fragmentation are probably main reasons for the decline of these species in farmland, since they directly affect both food availability and reproduction.

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Annual and long-term variation in the survival rates of British lapwings *Vanellus vanellus*

W.J. Peach, P.S. Thompson & J.C. Coulson

Peach, W.J., Thompson, P.S., & Coulson, J.C. 1994. Annual and long-term variation in the survival rates of British lapwings *Vanellus vanellus*.

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W.J. Peach, British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU.

P.S. Thompson & J.C. Coulson, Department of Biological Sciences, University of Durham, Science Laboratories, South Road, Durham, DH1 3LE.

In many parts of Britain and in other parts of western Europe, the lapwing *Vanellus vanellus* is declining. In order to determine if the decline in numbers was associated with a reduction in adult or first year survival rates, an analysis of British ringing recoveries was conducted.

There was no evidence that survival after the first year of life was age-dependent.

Mean adult survival (1930-88) is estimated at 0.705 ± 0.031 ($\pm 95\%$ confidence intervals). Since 1960, adult survival has increased to 0.752 ± 0.046 . Two weather variables (mean winter soil temperature and total winter rainfall) explained 69% of the variation in adult survival rates between 1961 and 1979. Mean first-year survival (1930-87) is estimated at 0.595 ± 0.040 ($\pm 95\%$ confidence intervals). As in the adults, the same two weather variables (mean winter soil temperature and total winter rainfall) explained 55% of the variation in first-year survival rates between 1959 and 1979.

In order to replace annual adult losses, lapwings should produce in the region of 0.83-0.97 fledglings per pair each year. From a review of the available literature, lapwings produced enough fledglings to maintain the population in only 8 out of 24 studies.

Reference

Peach, W.J., Thompson, P.S. & Coulson, J.C. 1994. Annual and long-term variation in the survival rates of British lapwings *Vanellus vanellus*. *Journal of Animal Ecology* 63: 60-70.

Concluding remarks

The Joint Nature Conservation Committee (JNCC), with the country conservation agencies English Nature, Scottish Natural Heritage and the Countryside Council for Wales, are the statutory bodies responsible for advising Government and others on nature conservation matters. These matters may be of a local, national or international dimension. The JNCC also has a remit to co-ordinate relevant research which underpins conservation strategies and to disseminate the results of this research to a wide audience. Workshops such as this, whether they relate to a species- or habitat-specific issue, are valuable fora for presenting and discussing recent research results and interpreting these for conservation action.

This particular publication, which forms part of the JNCC UK Nature Conservation series, draws together a wealth of information on the ecology of the lapwing *Vanellus vanellus*. The basis for the volume was the review paper presented at the British Trust for Ornithology Workshop in 1990, as well as a number of abstracts of papers which have subsequently been published elsewhere in the scientific literature. The results from other relevant studies which followed the initial workshop are also now known and some of these have also been drawn upon here. The ecology of the lapwing, its current population status, reasons for its decline and appropriate measures for the effective conservation of the species are all outlined. This publication is intended to be an important reference source for those people who wish to obtain an insight into the factors influencing lapwing populations.

A number of important international Directives and Conventions set out requirements for the conservation of bird species. Take, for example, the EC Directive on the Conservation of Wild Birds (EC/79/409). This Directive is one of the most important pieces of Community legislation on the environment and requires Member States of the European Union to protect bird species and the habitats upon which they are dependent. The 'Birds Directive' sets out requirements for the protection and management of bird species throughout all stages of their life cycle. In this context site-safeguard measures, subsequent management of protected areas, the

maintenance of sympathetic management throughout the wider countryside and the re-creation of damaged habitats are all required.

With these mechanisms for the conservation of species in place it is understandable why many people believe that the maintenance of bird populations such as the lapwing is assured. However, this is unfortunately not the case.

The lapwing, although still widespread, is one of many species dependent on 'agricultural' habitats which has declined in numbers and contracted in range during the last 20 years, both within the United Kingdom and in other European countries. These changes are detailed in Section 2 of the main review paper in this volume (Hudson, Tucker & Fuller 1994) and in the abstracts by Shrubbs & Lack (1994) and O'Brien & Smith (1994). As a species that is predominantly found breeding on agricultural land there is little doubt that the changes noted are related to changed agricultural practices. The rate at which development of intensive agriculture, in both upland and lowland areas, has taken place has rendered much of the agricultural landscape less suitable for many species and to the lapwing in particular. Studies of the use of farmland habitats by lapwings, such as those documented in the papers by Beintema & Visser (1994), Baines (1994) and Pearson & Stoate (1994), demonstrate the key areas of farming practice which significantly alter the availability of its preferred habitat. The switch from spring-sown to autumn-sown cereal crops, the drainage and more intensive management of pasture and a reduction in the availability of soil invertebrates through an increased usage of pesticides are highlighted as contributing factors to the decline of lapwings.

Where do we go from here?

For conservationists and researchers alike there are several challenges:

1. To identify gaps in our existing knowledge and to establish appropriate studies to improve our understanding of the ecological processes involved in changing population status.
2. To improve the impact and effectiveness of conservation mechanisms by setting

positive, yet realistic, targets for the maintenance and enhancement of the populations of bird species, such as the lapwing.

Recent undertakings made by the UK Government, under the international Convention on Biological Diversity signed at the Earth Summit in Rio de Janeiro in 1992, aim to ensure the sustainable use of biological resources and provide a new framework within which the conservation of any single species such as the lapwing should sit. The recent publication of the *Biodiversity: the UK action plan* (Department of Environment 1994) and *Biodiversity challenge* (Butterfly Conservation *et al.* 1993) further demonstrates the commitment from within both the statutory and voluntary sectors respectively to develop national plans and work within agreed frameworks. These will in time cover broad conservation objectives and detailed species- or habitat-specific targets which are aimed at conserving biodiversity.

Within the UK Biodiversity Action Plan 59 objectives are set out. The implementation of many of these objectives should contribute to enhancing the conservation status of lapwing. For example, the UK Government and statutory agencies aim to "*continue support and advice to farmers to help them to identify and adopt environmentally beneficial management practices*" and to "*continue to monitor existing financial incentives to encourage environmentally sensitive forms of agriculture to ensure they are having positive effects on the habitats and landscapes targeted*" (Department of the Environment 1994).

We now need to utilise the results of research and seize upon the opportunities presented here to achieve specific conservation targets. By working together we should be able to ensure that there is a sufficient diversity and area of habitat available to enhance the lapwing population throughout its traditional range across the UK.

Dr Colin Galbraith
Joint Nature Conservation Committee

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