

FINAL REPORT

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Arable Stewardship: impact of the pilot scheme on the brown hare and grey partridge after five years

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SUMMARY

In 2002, surveys of two farmland Biodiversity Action Plan species, brown hare *Lepus europaeus* and grey partridge *Perdix perdix*, were undertaken on a total of *ca* 40 Arable Stewardship Pilot Scheme farms and *ca* 40 non-agreement (control) farms in East Anglia and the West Midlands; the farms had previously been surveyed in 1998. The aim was to compare changes in winter density (brown hare), autumn density (grey partridge) and productivity (grey partridge) between 1998 and 2002 to determine whether the two species benefited from the scheme.

Overall, the densities of both brown hare and grey partridge were at least three times higher in East Anglia than in the West Midlands, which resulted in often much reduced sample sizes for the latter region. In East Anglia, the relative increase in brown hare density from 1998 to 2002 within each agreement farm (+35%) was significantly higher than that within each control farm (-18%); in the West Midlands numbers appeared to remain roughly stable on both types of farm. Adult grey partridge densities fell by approximately half from 1998 to 2002 in both regions, with no detectable difference between agreement and control farms. Grey partridge breeding productivity showed a significant twofold improvement on agreement farms relative to control farms over the same period, so that in 2002 the young-to-old ratio was four times higher, and the mean brood size two times greater, on agreement farms than on control ones. The improved productivity meant that total autumn densities of grey partridges (adults and juveniles) in East Anglia dropped by less on agreement farms (-30%) than on control farms (-60%). No meaningful differences were apparent for grey partridge in the West Midlands because of small sample sizes. For both species, additional forms of game and land management, ascertained by questioning the farmers, had no detectable effect on the results.

The outcome substantiates the view that a previous evaluation survey in 2000 had not allowed sufficient time for the Arable Stewardship options to mature. The benefits observed in 2002 are likely to increase further over time, and as more farmers take up the arable options now available under Countryside Stewardship.

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1. INTRODUCTION

The brown hare (*Lepus europaeus*) and the grey partridge (*Perdix perdix*) are both species that predominantly occupy farmland and have declined in abundance over the last 40 years (Potts, 1986; Tapper 1995; Hutchings & Harris 1996; Siriwardena, *et al.* 1998). The UK's brown hare population is estimated to have declined in abundance on farmland by 75% since World War 2 (Hutchings & Harris 1996) and the grey partridge has been estimated to have declined by about 85% during the period 1968 to 1999 (Baillie *et al.* 2002). In recognition of these declines both the brown hare and grey partridge are now UK Biodiversity Action Plan (BAP) species and as such the UK Government has undertaken to introduce measures that will halt the decline of the two species and aid their recovery.

The brown hare has been well studied; the results of this research show that the switch from mixed rotational farming, incorporating grass and spring-sown cereals, to farming systems without the grass rotation and dominated by winter-sown crops has reduced food availability and lowered hare numbers (Tapper & Barnes 1986; Tapper 1989).

The grey partridge is probably the most researched species of farmland bird, having been studied in detail since the 1930s (e.g. Middleton 1936, Blank *et al.* 1967, Potts 1986, Aebischer & Potts 1997). This research has linked the substantial decline experienced by the species with post-war modernisation of agriculture, particularly since the 1950s and 1960s (Potts 1986). The increased use of pesticides has resulted in a loss of invertebrates in cereal fields. Invertebrates form the major component of a grey partridge chick's diet during the first 10 days of its life and consequently this has resulted in reduced chick survival and breeding productivity (Green *et al.* 1987). Another consequence of agricultural intensification has been the loss of suitable grey partridge nesting habitat, which is mainly vegetation on grassy banks around field margins, hedge bottoms and autumn-sown cereals. Hedgerow removal and the enlargement of fields has been the main cause (Rands 1987).

The research into both these species has suggested a number of management options that may mitigate the negative effects of modern intensive farming. To aid the conservation of brown hares it has been suggested that woodland and cover crops (e.g. set-aside) should be encouraged on all farm types and on arable-dominated areas, grass leys should be used and areas of pasture established. On pasture-dominated areas farmers should be encouraged to incorporate fields of arable crops (Panek & Kamieniarz 1999; Vaughan *et al.* 2003). For the grey partridge the aim is to increase the abundance of broadleaved weeds and invertebrates in cereal fields (e.g. conservation headlands, brood-rearing strips) and provide nesting habitats (e.g. beetle banks). These management options have been field-tested and shown to enhance grey partridge numbers (e.g. Rands 1986, Sotherton *et al.* 1988).

As a result, many of these options were included within the Arable Stewardship Pilot Scheme, a Government-funded agri-environment scheme that was launched in January 1998 by the then Ministry of Agriculture, Fisheries and Food (MAFF), in two pilot areas in England. It sought to contribute to the achievement of BAP targets, by offering arable farmers a range of management options that were designed to create suitable habitat or conditions for plant and animal species that had declined or were threatened on arable farmland. Entry to the pilot scheme closed in 2000, but a number of these "Arable Options" were incorporated into the Countryside Stewardship Scheme from 2002 onwards.

The aim of the pilot was to test the arable measures under a range of arable farming systems and conditions. The East Anglian pilot area was dominated by cereal farming on heavy soils, but included lighter chalk soils. The West Midland area had a range of soil types and cropping, and a significant amount of mixed farming. In 1998-2000, MAFF commissioned an ecological evaluation to determine the influence of the options on the creation of wildlife habitats and abundance of threatened or scarce wildlife species. The Game Conservancy Trust, nominated lead partner for the brown hare and grey partridge under the UK BAP, monitored the brown hare and grey partridge as part of this evaluation. No significant increase in brown hare abundance was detected and no significant differences in the autumn density and productivity of grey partridges appeared between agreement farms and control farms. The short period of the study was thought to be the most likely reason for the lack of response (Tapper 2001, Tapper & Aebischer 2001). Now, two years later, the options will have matured and the expected benefits should be apparent.

Since 2001, one of MAFF's, and now the Department for Environment, Food and Rural Affairs' (Defra) Public Service Agreement (PSA) targets has been to reverse the long-term decline in abundance of farmland birds, of which the grey partridge is one of the most seriously affected. It is therefore important to assess whether Arable Stewardship and hence Arable Options are capable of delivering more brown hares and grey partridges, in order for the Government to meet both its BAP and its PSA targets.

The present study investigates whether, after five years, the Arable Stewardship Pilot Scheme has resulted in an increase in i) brown hare abundance, ii) partridge numbers and productivity, on farms that were initially surveyed in 1998.

2. METHODOLOGY

2.1. Data collection

2.1.1. *Brown hare*

All agreement and control farms that were surveyed in winter 1998/99 were approached in 2002 to see if they would allow repeat surveys (Tapper 2002). In 2002 permission was not obtained for three East Anglian farms (one agreement and two control) and six West Midlands farms (one agreement, five controls). Agreement holders are usually obliged to allow monitoring of their agreements. However, this obligation was waived by Defra for the two agreement farms where permission was refused, as the agreement holder had changed since the original survey. In total 71 farms were surveyed, 19 agreement and 18 control farms in East Anglia and 19 agreement and 15 control farms in the West Midlands.

The protocol used to count brown hares in winter 1998/99 was followed exactly in winter 2002/03. The surveys were carried out from the beginning of November 2002 to the end of February 2003. Before a survey began, each farm was visited in the late afternoon to determine access and to locate the counting points. Access permitting, each field typically had at least one counting point, so the number of counting points and area counted on each farm were determined by the number of fields on the farm. In most cases at least 20 fields were counted, representing at least 30% of the farm area. At each counting point the area counted was mapped so that the area surveyed could be measured.

Hares were counted after dark using a 4WD vehicle, a handheld spotlight and binoculars. At each counting point the spotlight was slowly swung in an arc across the counting area and hares were counted using binoculars. Hares usually showed up by eye shine, but their body shape and colour also indicated their presence. The location of brown hares (and other wild mammals observed) were recorded on maps, together with information on crop type. Any areas that could not be seen properly or counted were marked on the maps. Counting was not carried out on particularly rainy, windy, foggy or cold nights.

The count areas for 1998/99 and 2002/03 were digitised and their areas calculated. These areas could differ between years because of occasional difficulties in accessing counting points, but on average the differences were small.

To enhance readability, we refer to the winter periods 1998/99 and 2002/03 as simply “1998” and “2002” respectively in the other sections of this report dealing with brown hares.

2.1.2. *Grey partridge*

All agreement and control farms that were surveyed in autumn 1998 were approached in 2002 to see if they would allow repeat surveys (Tapper & Aebischer 2001). In 2002 access was denied on three East Anglian farms (two agreement and one control) and three West Midlands farms (all controls). In total 76 farms were surveyed, 20 agreement and 19 control farms in East Anglia and 20 agreement and 17 control farms in the West Midlands.

The protocol used to count grey partridges in autumn 1998 was followed exactly in autumn 2002. Each farm was surveyed during either a single early morning or late evening visit,

which took place either 2-3 hours after first light or before dark. For farms that were less than 200 ha, all suitable fields (i.e. those that could be driven around) were surveyed. Grass fields containing livestock or fields that had been cultivated or drilled were scanned from a number of vantage points. For farms that were larger than 200 ha as much area as possible was surveyed within the available time.

The surveys involved two people, a driver and a recorder, driving around all accessible fields in a 4WD vehicle. The vehicle was driven along the headland around all fields, and in large fields or in fields where the topography hindered visibility, it was driven along parallel transects up and down the field until the ground was completely covered. Both observers scanned the field in front of and to the side of the moving vehicle with the naked eye. When a covey of partridges was seen the vehicle was stopped and both observers used binoculars to count, age and sex the birds.

Wet weather during the harvest period and concerns among the farmers about wet weather hindering cultivation made counting difficult. The harvest was very protracted and in many cases the plough immediately followed the combine. The counting in 2002 began on 19 August and was completed by 16 September.

The boundaries of the areas counted on each farm in 1998 and in 2002 were digitised and their areas calculated. The areas counted could vary considerably between years for the same farm because the countable area was dependent on crop rotation and the state of the harvest.

2.1.3. Game and land management questionnaire

Each farmer was asked a number of questions about game and land management undertaken on the farm. Specifically, farmers were asked whether they had a gamekeeper, if game releasing or shooting took place, if they undertook habitat management targeted directly at helping game (game cover), or if they had set-aside in the Wild Bird Cover option. This would highlight whether fluctuations in brown hare and grey partridge numbers were due in part to releasing, shooting or game management. Additionally we asked if they had problems with poaching, as poaching may have reduced game numbers either directly, or indirectly by farmers reducing game numbers to prevent it. Information was collected on access as brown hares are known to avoid areas with high numbers of people. On control farms we asked whether the farmer undertook any conservation measures for wildlife and on agreement farms we asked if they had any non-arable Countryside Stewardship Scheme options, which may have a number of benefits for brown hares and grey partridges in addition to those of the Arable Stewardship Pilot Scheme. The results of the questionnaire are summarised in Appendix 1.

2.2. Statistical analysis

The analyses sought to test whether the management undertaken on agreement farms had increased brown hare abundance or grey partridge abundance and productivity during the five-year period between 1998 and 2002 relative to control farms. Because the change was expected to be positive, statistical tests of the corresponding null hypothesis were one-tailed. Data from the two pilot areas were examined separately.

2.2.1. Densities of brown hares and grey partridges

The numbers of brown hares and grey partridges recorded on each farm in relation to the area counted provided a measure of winter hare density and two measures of partridge density (numbers of adults gave an indication of breeding stocks, and total numbers of adults + young gave autumn densities).

There were two ways of looking at changes in density, an across-farm approach and a within-farm approach.

The across-farm approach examined how the overall number of animals counted, in relation to the total area counted, varied between years according to agreement status. Statistically, this approach was equivalent to modelling the numbers of animals on each farm in each year using loglinear regression, specifying a Poisson error structure and a logarithmic link function. $\text{Log}(\text{area counted})$ was specified as an offset in the model so that effectively the variable being analysed was density (number/area). The analyses excluded farms with no hares or no grey partridges recorded in either year because those farms contributed no information about change.

In order to test for the effect of treatment (agreement vs. control), the statistical model had to take into account (i) variation between individual farms and (ii) variation between years (1998 vs. 2002). Therefore the specified model was:

$$Y = \text{constant} + \text{farm} + \text{year} + \text{agreement status}$$

Farm was a multi-level factor equal to the number of farms in each pilot area, year was a 2-level factor (1 = 1998, 2 = 2002), and agreement status was a 2-level factor (1 = all sites in 1998 and control sites in 2002, 2 = agreement sites in 2002).

In the loglinear regressions, tests were based on mean deviance ratios, approximately distributed as F-ratios, to allow for overdispersion.

The within-farm approach considered changes in the densities of hares and partridges at the local level. For each farm, density in 1998 and in 2002 was $\log(x+1)$ -transformed, and the 1998 value subtracted from the 2002 value to give a farm-specific measure of change. The average measures of change for agreement and control farms were then compared by analysis of variance.

The measures of change c thus obtained were on a logarithmic scale. The corresponding percentage changes p were obtained by the formula $p = 100 * [\exp(c) - 1]$. The 95% confidence limits of p were obtained by applying the same transformation to the 95% confidence limits of c . Approximate standard errors of p were derived by first-order Taylor series linearisation according to the formula $\text{se}(p) = p \text{ se}(c)$ (Seber 1982).

2.2.2. Grey partridge productivity

The young-to-old ratio (Y:O) and the number of young per brood (mean brood size) provided two measures of grey partridge productivity.

To test for an effect of agreement status, the young-to-old ratio was modelled using least-squares regression. The variable was $\log(x+1)$ -transformed before analysis to normalise its distribution, and the number of adults forming the denominator in the ratio was used to weight the analysis. Analysis of brood size used the number of young birds as dependent variable in a loglinear regression (Poisson error, logarithmic link), specifying $\log(\text{number of broods})$ as an offset.

2.2.3. Questionnaire answers

Two control farms in East Anglia and none in the West Midlands took up arable options under the Countryside Stewardship Scheme in 2001. The analyses comparing control and agreement farms were rerun excluding them, but the results remained the same throughout and are not reported on further.

The presence of non-arable Countryside Stewardship options applied only to agreement farms, and that of wildlife conservation measures applied only to control farms. In these cases, we restricted the analyses to agreement and control farms respectively, and compared farms with and without the corresponding management using statistical models matching those described in 2.2.1.

All other game and land management factors were coded as 0 (answer no) or 1 (answer yes), except for the number of hares and partridges shot, which were $\log(x+1)$ -transformed. For all density variables, each factor in turn was then included in the models specified under 2.2.1, and the difference between control and agreement farms was tested after taking the factor into account (one-tailed test). The presence of a significant interaction between each factor and agreement status was tested by adding the interaction term to the model.

3. RESULTS

3.1. Brown hare: winter density

3.1.1. Brown Hare winter density v. agreement status

In both 1998 and 2002, winter densities of brown hares were roughly four times higher in East Anglia than in the West Midlands. One consequence was that on 7 West Midland farms, no hares were recorded in either 1998 or 2002, which reduced the sample size by a quarter compared with East Anglia.

In East Anglia in 1998, hare densities were a third higher on agreement farms than on control farms, while in 2002 they were two-thirds higher (Table 3.1.1). In the across-farm comparison, the relative increase in density from 1998 to 2002 was, on average, 23% higher on agreement farms than on control farms, although the difference was not significant (95% confidence limits -14% to +76%). In the within-farm comparison, the mean change from 1998 to 2002 was 65% higher on agreement farms than on control farms (95% confidence limits +3% to +163%) (Table 3.1.2).

Table 3.1.1. Counts and densities of brown hares by pilot area, year and farm type, on farms surveyed in both 1998 and 2002.

	Farms	1998			2002		
		Hares counted	Area counted (km ²)	Density	Hares counted	Area counted (km ²)	Density
East Anglia							
Control	18	326	27.00	12.07±2.59	326	26.88	12.13±3.27
Agreement	19	502	30.93	16.23±3.35	618	30.90	20.01±3.77
West Midlands							
Control	15	54	15.62	3.46±0.89	55	15.62	3.52±1.13
Agreement	19	125	25.78	4.85±1.49	111	25.74	4.31±1.09

Table 3.1.2. Percentage change in density of brown hares on control and agreement farms in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
Control	18	0.5 ± 14.8	-17.9 ± 15.0
Agreement	19	23.2 ± 18.8	35.0 ± 27.9
Test of difference		F _{1,35} = 0.94, n.s.	F _{1,35} = 3.22, P < 0.05
West Midlands			
Control	13	1.8 ± 22.8	3.6 ± 16.9
Agreement	14	-11.1 ± 28.4	-10.8 ± 32.2
Test of difference		F _{1,25} = 0.09, n.s.	F _{1,25} = 0.09, n.s.

In the West Midlands, hare densities were a third higher on agreement farms than on control farms in both 1998 and 2002 (Table 3.1.1). Across-farm and within-farm changes were similar; the relative increase in density from 1998 to 2002 was, on average, 14% lower on agreement farms than on control farms but the difference was not significant and the 95% confidence interval large (95% confidence limits, across farms: -60% to +89%; within farms: -57% to +74%) (Table 3.1.2).

3.1.2. Brown Hare winter density v. questionnaire answers

(a) Wildlife habitat creation on control farms

In East Anglia, the change in densities on control farms where wildlife habitat creation had taken place (Table 3.1.3) did not differ significantly from that on control farms where no wildlife habitats had been created, either on an across-farm basis or on a within-farm one. The same held in the West Midlands (Table 3.1.3).

Table 3.1.3. Percentage change in density of brown hares on control farms where wildlife habitat creation had or had not taken place in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	9	-9.8 ± 17.7	-13.3 ± 17.7
Yes	9	11.1 ± 24.7	-22.3 ± 24.5
Test of difference		$F_{1,16} = 0.49$, n.s.	$F_{1,16} = 0.09$, n.s.
West Midlands			
No	6	-3.1 ± 38.4	-12.4 ± 24.7
Yes	7	9.1 ± 26.1	19.6 ± 22.2
Test of difference		$F_{1,11} = 0.06$, n.s.	$F_{1,11} = 0.90$, n.s.

(b) Non-arable Countryside Stewardship agreement farms

In East Anglia, the change in densities on agreement farms where non-arable Countryside Stewardship options had been taken up did not differ significantly from that on agreement farms with no non-arable Countryside Stewardship options, either on an across-farm basis or on a within-farm one. The same held for the West Midlands (Table 3.1.4).

(c) Game and land management factors relevant to all farms

Overall, adjusting the analysis to take into account the effect of game and land management factors had a minimal effect (Table 3.1.5). None of the interactions was significant, and the significance of the effect of agreement status remained unchanged except in East Anglia where, after taking into account keeping, the effect of agreement status slipped below the threshold for significance in the within-farm comparison.

Table 3.1.4. Percentage change in density of brown hares on agreement farms where non-arable Countryside Stewardship had or had not been instigated in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	13	16.1 ± 18.4	21.0 ± 25.5
Yes	6	59.5 ± 54.4	71.1 ± 84.1
Test of difference		$F_{1,17} = 0.06$, n.s.	$F_{1,17} = 0.59$, n.s.
West Midlands			
No	8	-45.3 ± 23.3	-30.1 ± 39.0
Yes	6	97.0 ± 74.5	23.5 ± 51.0
Test of difference		$F_{1,12} = 4.56$, n.s.	$F_{1,12} = 0.59$, n.s.

Table 3.1.5. Tests for differences in winter hare density between agreement and control farms after taking into account game and land management, across farms and within farms, on farms surveyed in both 1998 and 2002. *: $P < 0.05$.

	Factor taken into account when testing for an effect of agreement							
	Game keeper	Game releasing	Game cover	Game feeding	No. shot	Poaching	Access	WBC
East Anglia								
<i>Across farms</i>								
Main effect ($F_{1,34}$)	0.79	1.63	1.08	0.94	1.25	0.92	1.05	0.91
Interaction ($F_{1,33}$)	0.31	0.95	0.22	0.08	1.22	2.09	2.78	1.70
<i>Within farms</i>								
Main effect ($F_{1,34}$)	2.76	3.97 *	3.53 *	3.35 *	3.09 *	3.11 *	3.79 *	3.58 *
Interaction ($F_{1,33}$)	0.46	0.75	0.25	0.07	2.10	0.81	1.07	2.35
West Midlands								
<i>Across farms</i>								
Main effect ($F_{1,24}$)	0.16	0.13	0.29	0.29	0.06	0.06	0.00	0.05
Interaction ($F_{1,23}$)	0.18	0.10	2.20	0.29	0.45	0.12	1.43	0.02
<i>Within farms</i>								
Main effect ($F_{1,24}$)	0.28	0.10	0.35	0.29	0.16	0.04	0.18	0.28
Interaction ($F_{1,23}$)	0.08	0.20	0.26	0.09	0.15	0.02	0.73	0.03

3.2. Grey partridge: autumn density

3.2.1. Grey partridge autumn density v. agreement status

Overall, autumn densities of grey partridges were roughly five times higher in East Anglia than in the West Midlands. Coupled with high between-farm variation, this led to 10 East Anglian and 16 West Midland farms with no grey partridges recorded in either 1998 or 2002.

In East Anglia in 1998, grey partridge autumn densities were 74% higher on agreement farms than on control farms, while in 2002 they were over three times higher (Table 3.2.1). In the across-farm comparison (Table 3.2.2), the relative increase in autumn density from 1998 to 2002 was, on average, 150% higher on agreement farms than on control farms, although the difference was not significant (95% confidence limits -12% to +591%). In the within-farm comparison (Table 3.2.2), the relative increase from 1998 to 2002 was 59% higher on agreement farms than on control farms (95% confidence limits -34% to +286%).

In the West Midlands, grey partridge autumn densities were over twice as high on agreement farms as on control farms in 1998, but densities were the same in 2002 (Table 3.2.1). Across-farm change (Table 3.2.2) was, on average, 50% lower on agreement farms than on control farms (95% confidence limits -57% to +74%). The within-farm decrease (Table 3.2.2) averaged 16% lower on agreement farms than on control farms (95% confidence limits -70% to +138%).

Table 3.2.1. Total autumn counts and densities of grey partridges (adults and young) by pilot area, year and farm type, on farms surveyed in both 1998 and 2002.

	Farms	1998			2002		
		Birds counted	Area counted (km ²)	Density	Birds counted	Area counted (km ²)	Density
East Anglia							
Control	19	154	27.92	5.51±2.07	50	28.02	1.78±0.46
Agreement	19	361	37.67	9.58±2.89	275	34.88	7.60±2.45
West Midlands							
Control	17	28	20.76	1.35±0.66	20	24.95	0.80±0.59
Agreement	20	80	27.11	2.95±1.03	24	29.98	0.80±0.48

Table 3.2.2. Percentage change in autumn density of grey partridges on control and agreement farms in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
Control	11	-69.9 ± 12.8	-57.5 ± 17.6
Agreement	17	-26.0 ± 22.2	-32.4 ± 24.9
Test of difference		F _{1,26} = 2.40, n.s.	F _{1,26} = 0.81, n.s.
West Midlands			
Control	9	-38.4 ± 44.9	-24.0 ± 39.8
Agreement	12	-69.5 ± 21.1	-35.5 ± 32.0
Test of difference		F _{1,19} = 0.62, n.s.	F _{1,19} = 0.08, n.s.

3.2.2. Grey partridge autumn density v. questionnaire answers

(a) Wildlife habitat creation on control farms

In East Anglia, the change in autumn densities on control farms where wildlife habitat creation had taken place (Table 3.2.3) did not differ significantly from that on control farms where no wildlife habitats had been created, either on an across-farm basis or on a within-farm one. The same held in the West Midlands where, despite large apparent differences, the variation was also large (Table 3.2.3).

Table 3.2.3. Percentage change in autumn density of grey partridges on control farms where wildlife habitat creation had or had not taken place in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	7	-75.7 ± 14.1	-59.7 ± 24.4
Yes	4	-54.9 ± 28.8	-53.2 ± 25.0
Test of difference		$F_{1,9} = 0.47$, n.s.	$F_{1,9} = 0.06$, n.s.
West Midlands			
No	5	-87.1 ± 15.8	-53.6 ± 26.8
Yes	4	98.3 ± 212.2	41.0 ± 131.0
Test of difference		$F_{1,7} = 3.54$, n.s.	$F_{1,7} = 1.54$, n.s.

(b) Non-arable Countryside Stewardship options on agreement farms

In East Anglia, the change in autumn densities on agreement farms where non-arable Countryside Stewardship options had been taken up did not differ significantly from that on agreement farms with no non-arable Countryside Stewardship options (Table 3.2.4), either on an across-farm basis or on a within-farm one. The same held for the West Midlands (Table 3.2.4).

Table 3.2.4. Percentage change in autumn density of grey partridges on agreement farms where non-arable Countryside Stewardship had or had not been instigated in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	11	-13.1 ± 33.6	-11.7 ± 39.9
Yes	6	-46.8 ± 26.4	-58.7 ± 26.3
Test of difference		$F_{1,15} = 0.14$, n.s.	$F_{1,15} = 1.03$, n.s.
West Midlands			
No	5	-61.1 ± 43.6	-41.5 ± 39.0
Yes	7	-77.7 ± 21.8	-30.8 ± 38.9
Test of difference		$F_{1,10} = 0.14$, n.s.	$F_{1,10} = 0.01$, n.s.

(c) Game and land management factors relevant to all farms

Overall, adjusting the analysis to take into account the effect of game and land management factors had no effect (Table 3.2.5). None of the interactions was significant, and the significance of the effect of agreement status remained unchanged throughout.

Table 3.2.5. Tests for differences in autumn grey partridge density between agreement and control farms after taking into account game and land management, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Factor taken into account when testing for an effect of agreement							
	Game keeper	Game releasing	Game cover	Game feeding	No. shot	Poaching	Access	WBC
East Anglia								
<i>Across farms</i>								
Main effect ($F_{1,25}$)	2.31	2.54	2.31	2.27	0.86	1.63	2.36	1.04
Interaction ($F_{1,24}$)	3.31	3.13	1.85	1.94	0.05	2.86	n/a	0.01
<i>Within farms</i>								
Main effect ($F_{1,25}$)	0.84	1.53	0.67	0.77	0.23	0.88	0.73	0.57
Interaction ($F_{1,24}$)	3.92	2.69	2.70	1.58	0.02	1.96	n/a	0.00
West Midlands								
<i>Across farms</i>								
Main effect ($F_{1,18}$)	0.48	0.37	0.46	0.44	0.52	0.95	0.40	0.23
Interaction ($F_{1,17}$)	0.95	0.29	2.71	0.68	0.17	0.03	0.12	0.15
<i>Within farms</i>								
Main effect ($F_{1,18}$)	0.02	0.07	0.05	0.02	0.13	0.21	0.06	0.04
Interaction ($F_{1,17}$)	0.87	0.04	1.63	0.33	0.16	0.03	0.66	0.04

3.3. Grey partridge: adult density

3.3.1. Grey partridge adult density v. agreement status

As for the autumn totals, densities of adult grey partridges were roughly five times higher in East Anglia than in the West Midlands. The numbers of farms with no adult grey partridges in either 1998 or 2002 were the same as in section 3.2.1.

In East Anglia, adult grey partridge densities were around twice as high on agreement farms as on control farms in both 1998 and 2002 (Table 3.3.1). In both across-farm and within-farm comparisons (Table 3.3.2), the relative change from 1998 to 2002 was practically identical on the two types of farm (across-farm: 95% confidence limits of change on agreement farms relative to control ones -59% to +158%; within-farm: 95% confidence limits -50% to +100%).

In the West Midlands, adult grey partridge densities were similar on agreement farms and on control farms in both 1998 and 2002 (Table 3.3.1). In both across-farm and within-farm comparisons (Table 3.3.2), the relative change from 1998 to 2002 was also similar on the two

types of farm (across-farm: 95% confidence limits of change on agreement farms relative to control ones -84% to +369%; within-farm: 95% confidence limits -51% to +128%).

Table 3.3.1. Counts and densities of adult grey partridges by pilot area, year and farm type, on farms surveyed in both 1998 and 2002.

	Farms	1998			2002		
		Birds counted	Area counted (km ²)	Density	Birds counted	Area counted (km ²)	Density
East Anglia							
Control	19	66	27.92	2.36±0.81	32	28.02	1.14±0.41
Agreement	19	184	37.67	4.88±1.48	84	34.88	2.41±0.74
West Midlands							
Control	17	12	20.76	0.58±0.29	9	24.95	0.36±0.17
Agreement	20	21	27.11	0.77±0.20	12	29.98	0.40±0.23

Table 3.3.2. Percentage change in density of adult grey partridges on control and agreement farms in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
Control	11	-55.5 ± 19.2	-44.9 ± 17.2
Agreement	17	-54.3 ± 13.3	-44.6 ± 14.1
Test of difference		F _{1,26} = 0.01, n.s.	F _{1,26} = 0.01, n.s.
West Midlands			
Control	9	-35.0 ± 44.5	-17.4 ± 27.6
Agreement	12	-44.2 ± 37.0	-12.8 ± 25.5
Test of difference		F _{1,19} = 0.02, n.s.	F _{1,19} = 0.62, n.s.

3.3.2. Grey partridge adult density v. questionnaire answers

(a) Wildlife habitat creation on control farms

In East Anglia, the change in densities on control farms where wildlife habitat creation had taken place (Table 3.3.3) did not differ significantly from that on control farms where no wildlife habitats had been created, either on an across-farm basis or on a within-farm one. The same held in the West Midlands (Table 3.3.3).

Table 3.3.3. Percentage change in density of adult grey partridges on control farms where wildlife habitat creation had or had not taken place in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	7	-68.7 ± 17.1	-51.1 ± 21.3
Yes	4	-14.8 ± 58.7	-31.8 ± 31.2
Test of difference		$F_{1,9} = 1.28$, n.s.	$F_{1,9} = 0.24$, n.s.
West Midlands			
No	5	-67.5 ± 36.7	-28.4 ± 19.5
Yes	4	10.3 ± 90.6	-1.1 ± 71.6
Test of difference		$F_{1,7} = 0.43$, n.s.	$F_{1,7} = 0.21$, n.s.

(b) Non-arable Countryside Stewardship options on agreement farms

In East Anglia, the change in densities on agreement farms where non-arable Countryside Stewardship options had been taken up did not differ significantly from that on agreement farms with no non-arable Countryside Stewardship options, either on an across-farm basis or on a within-farm one (Table 3.3.4). The same held for the West Midlands (Table 3.3.4).

Table 3.3.4. Percentage change in density of adult grey partridges on agreement farms where non-arable Countryside Stewardship had or had not been instigated in the two pilot areas, across farms and within farms, on farms surveyed in both 1998 and 2002.

	Farms	Across-farm change	Within-farm change
East Anglia			
No	11	-48.6 ± 18.5	-33.4 ± 21.3
Yes	6	-65.9 ± 18.3	-60.4 ± 16.6
Test of difference		$F_{1,15} = 0.03$, n.s.	$F_{1,15} = 0.96$, n.s.
West Midlands			
No	5	-48.0 ± 57.8	-19.4 ± 36.3
Yes	7	-42.1 ± 51.8	-7.7 ± 38.1
Test of difference		$F_{1,10} = 0.01$, n.s.	$F_{1,10} = 0.05$, n.s.

(c) Game and land management factors relevant to all farms

Generally, adjusting the analysis to take into account the effect of game and land management factors had little effect (Table 3.3.5). All except one of the interactions were non-significant, and in those cases the significance of the effect of agreement status remained unchanged. The significant interaction was for keeping in the within-farms comparison. It was probably an artefact of small sample size, in that only 2 of the 11 control farms had no keeper, and both of them registered an unusually large increase from 1998 to 2002 because on each one a covey had been recorded in 2002 but not in 1998.

Table 3.3.5. Tests for differences in adult grey partridge density between agreement and control farms after taking into account game and land management, across farms and within farms, on farms surveyed in both 1998 and 2002. *: $P < 0.05$

	Factor taken into account when testing for an effect of agreement							
	Game keeper	Game releasing	Game cover	Game feeding	No. shot	Poaching	Access	WBC
East Anglia								
<i>Across farms</i>								
Main effect (F _{1,25})	0.01	0.01	0.01	0.00	0.06	0.03	0.00	0.38
Interaction (F _{1,24})	4.23	3.22	1.92	3.51	0.01	1.09	n/a	0.02
<i>Within farms</i>								
Main effect (F _{1,25})	0.01	0.12	0.00	0.00	0.05	0.00	0.00	0.01
Interaction (F _{1,24})	4.60 *	3.08	2.86	2.59	0.01	1.25	n/a	0.01
West Midlands								
<i>Across farms</i>								
Main effect (F _{1,18})	0.02	0.02	0.02	0.02	0.05	0.07	0.02	0.00
Interaction (F _{1,17})	0.25	0.02	0.19	0.01	0.89	0.01	0.04	0.61
<i>Within farms</i>								
Main effect (F _{1,18})	0.05	0.01	0.02	0.05	0.00	0.00	0.01	0.03
Interaction (F _{1,17})	0.69	0.11	0.30	0.11	0.88	0.03	0.73	0.11

3.4. Grey partridge: young-to-old ratio

3.4.1. Grey partridge young-to-old ratio v. agreement status

In East Anglia, the young-to-old ratio in 1998 was slightly lower on agreement farms than on control farms (Table 3.4.1). In contrast in 2002, the young-to-old ratio was four times higher on agreement farms than on control farms. This meant that the change in productivity from 1998 to 2002 on agreement farms was twice that on control farms ($F_{1,14} = 4.22$, $P < 0.05$; 95% confidence limits +10% to +240%). In the West Midlands, partridges were much sparser, so only for one control farm and one agreement farm was it possible to calculate young-to-old ratios in both years. This sample size was too small for a comparison of change.

Table 3.4.1. Young-to-old ratio (\pm s.e.) of grey partridges by area, year and farm type, based only on farms for which it could be calculated in both 1998 and 2002.

	Farms	1998			2002		
		Young	Old	Y:O	Young	Old	Y:O
East Anglia							
Control	7	70	57	1.23±0.10	14	27	0.52±0.19
Agreement	9	160	154	1.04±0.06	157	76	2.07±0.14
West Midlands							
Control	1	0	3	0.00	1	2	0.50
Agreement	1	0	2	0.00	1	1	1.00

Because sample sizes were so low, and because the difference between control and agreement farms was so small in 1998, the analysis was repeated based on all farms for which the young-to-old ratio could be calculated in any one year, and the comparison based solely on 2002 data (Table 3.4.2). As before, in East Anglia the young-to-old ratio in 1998 was slightly lower on agreement farms than on control farms. In 2002, it was four times higher on agreement farms than on control farms, and the difference was significant ($F_{1,19} = 14.22$, $P < 0.001$). In the West Midlands, the mean young-to-old ratio could be calculated on 10 farms in 2002, and was similar on both types of farm ($F_{1,8} = 0.16$, n.s.).

Table 3.4.2. Young-to-old ratio (\pm s.e.) of grey partridges by area, year and farm type, based on all farms for which it could be calculated in any one year.

	1998				2002			
	Farms	Young	Old	Y:O	Farms	Young	Old	Y:O
East Anglia								
Control	9	88	66	1.33 \pm 0.48	9	18	32	0.56 \pm 0.48
Agreement	15	177	184	0.96 \pm 0.05	12	187	86	2.20 \pm 0.13
West Midlands								
Control	5	16	12	1.33 \pm 0.59	5	11	9	1.22 \pm 0.46
Agreement	8	59	21	2.81 \pm 0.11	5	12	12	1.00 \pm 0.17

3.5. Grey partridge: brood size

3.5.1. Grey partridge brood size v. agreement status

In East Anglia, only 10 farms had broods in both 1998 and 2002; the mean brood size of grey partridges was lower on agreement than control farms in 1998, but the situation had reversed in 2002 (Table 3.5.1). This meant that the relative increase in brood size from 1998 to 2002 on agreement farms was over three times higher than on control farms ($F_{1,8} = 23.63$, $P < 0.001$; 95% confidence limits +100% to +435%). In the West Midlands, no farms had broods in both 1998 and 2002.

Table 3.5.1. Mean brood size (\pm s.e.) of young grey partridges in coveys, based only on farms for which it could be calculated in both 1998 and 2002.

	Farms	1998			2002		
		Young	Broods	Brood size	Young	Broods	Brood size
East Anglia							
Control	3	40	5	8.00±1.22	9	3	3.00±1.53
Agreement	7	160	30	5.33±0.32	144	23	6.26±0.29
West Midlands							
Control	0	-	-	-	-	-	-
Agreement	0	-	-	-	-	-	-

Because sample sizes were so low, the analysis was repeated based on all farms where broods were recorded in any one year, and the comparison based solely on 2002 data (Table 3.5.2). This increased the sample size to 17 farms in East Anglia and 6 in the West Midlands. In East Anglia the mean brood size in 1998 was slightly lower on agreement farms than on control farms, but in 2002 it was four times higher; the difference was significant ($F_{1,15} = 9.67$, $P < 0.01$). In the West Midlands, the difference was minor and not significant ($F_{1,4} = 0.01$, n.s.).

Table 3.5.2. Mean brood size (\pm s.e.) of young grey partridges in coveys by pilot area, year and treatment, based on all farms for which it could be calculated in any one year.

	1998				2002			
	Farms	Young	Broods	Brood size	Farms	Young	Broods	Brood size
East Anglia								
Control	7	88	13	6.77 \pm 1.38	5	18	6	3.00 \pm 2.52
Agreement	10	177	33	5.36 \pm 0.31	12	189	29	6.52 \pm 0.32
West Midlands								
Control	2	16	2	8.00 \pm 2.00	3	11	3	3.67 \pm 2.67
Agreement	6	59	9	6.56 \pm 0.72	3	12	3	4.00 \pm 0.82

4. DISCUSSION

The previous evaluation of brown hare abundance (Tapper 2001) and of grey partridge productivity and abundance (Tapper & Aebischer 2001) on agreement and control farms in 2000 found no improvement as a result of management instigated under the Arable Stewardship Pilot Scheme. As many of the options available under that scheme were based on techniques already tested successfully in the field, the lack of response was thought to be due to the small numbers of brown hares and grey partridges present on the pilot areas and insufficient time for the options to mature. Two years later, the fresh evaluation carried out in 2002 and reported here shows more promise, at least in East Anglia where densities of both species were on average over three times higher than in the West Midlands.

For brown hare, the increase in density from 1998 to 2002 within each farm was significantly higher, at +35%, on agreement farms than on control farms (-18%) in East Anglia. An alternative method of measuring change, which pooled data across farms as though all agreement areas were one big farm and all control ones another, attenuated the difference in rates of change so that it was no longer significant. However, the latter approach gave greater weight to areas with large numbers of hares, where the scope for increase was limited, at the expense of farms where large increases were recorded from low initial numbers in 1998. As it is arguably more important to restore hare numbers in low-density areas, we believe that the within-farm approach corresponded best to the objectives of the scheme. In the West Midlands, where sample size was three-quarters of that in East Anglia, the change from 1998 to 2002 was similar on the two types of farm.

The increase in brown hare densities in East Anglia appears to be directly due to habitat enhancement under the Arable Stewardship Pilot Scheme as no other game or land management factor contributed significantly to it.

For grey partridge, productivity as measured by the young-to-old ratio of birds in autumn doubled on agreement farms in East Anglia, but halved on control farms; the difference was significant. Likewise, mean brood size increased slightly on agreement farms in East Anglia, but fell by two-thirds on control farms. However, there was no evidence of any difference in the rate of change in density of adult grey partridges between agreement and control farms, with numbers halving on both. The good productivity on agreement farms was reflected in a considerably smaller fall (around 30%) in overall autumn density from 1998 to 2002 than on control farms (fall of around 60%).

It is worth noting that according to The Game Conservancy Trust's national Partridge Count Scheme, 2002 was a good year for partridge reproduction in East Anglia, and followed a succession of mainly poor years since 1995. If the benefits of Arable Stewardship options take effect mainly in years of good reproduction, then the lack of response for adults is perhaps not surprising. Based on the 2002 performance, and making the standard assumption of 45% annual survival (Potts 1986), we would expect the density of grey partridge adults on agreement farms to increase by 38% in 2003, and to drop by 32% on control ones. It is clear, therefore, that by raising breeding success through the provision of nesting cover and insect-rich brood-rearing habitat, the Arable Stewardship Pilot Scheme has the potential also to improve adult densities.

In the West Midlands, the low density of grey partridges resulted in high variation between farms, and in a collapse of sample sizes for assessing changes in productivity between 1998 and 2002 (two farms only for young-to-old ratio, none for brood size). As a consequence, measures of productivity and change in density were difficult if not impossible to measure precisely. The problem, for both brown hare and grey partridge, is illustrated by examining the 95% confidence limits of the rates of change in density from 1998 to 2002. For instance, the upper 95% confidence limit for the within-farm comparison was +89% for brown hare, +138% for overall autumn grey partridge density, and +128% for adult grey partridge density. The results are therefore not incompatible with a beneficial effect of Arable Stewardship options in the West Midlands as well as in East Anglia. It is certainly not possible to state with confidence that the Arable Stewardship Pilot Scheme had been less successful in the West Midlands.

In conclusion, the results presented here confirm, at least for East Anglia, that the Arable Stewardship Pilot Scheme benefits both the brown hare and the grey partridge after a suitable maturation period (about 4 years). As many of the Arable Stewardship Pilot options are now being extended nationally as Arable Options under the Countryside Stewardship Scheme, it is likely that the benefits to these two species will increase as the “hotspots” become less isolated. In addition, a number of arable options have been incorporated into the pilot “Entry Level Scheme”. If these are subsequently implemented at the landscape scale as part of the proposed Entry Level Scheme, we anticipate that they could have a positive effect and hence provide a major boost to the UK Biodiversity Action Plan for these species.

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APPENDIX 1: Questionnaire answers

The table below gives the number of respondents that answered yes or no to questions concerning game and land management on the farm, according to agreement status (percentages in brackets). Neither game nor land management carried out by farmers was significantly associated with agreement status within either region, although sample sizes were inadequate to detect small differences. Pooled over both regions, there was a significant association between agreement status and two aspects of game management, the presence of a gamekeeper and gamebird releasing. *: $P < 0.05$, **: $P < 0.01$

		East Anglia			West Midlands			Overall		
		Agreement	Control	χ^2_1	Agreement	Control	χ^2_1	Agreement	Control	χ^2_1
Gamekeeper	Yes	21 (91)	14 (64)	3.51, n.s.	19 (79)	10 (53)	2.29, n.s.	40 (85)	24 (59)	6.51, **
	No	2 (9)	8 (36)		5 (21)	9 (47)		7 (15)	17 (41)	
Releasing	Yes	16 (70)	10 (45)	1.78, n.s.	18 (75)	10 (53)	1.45, n.s.	34 (72)	20 (49)	4.18, *
	No	7 (30)	12 (55)		6 (15)	9 (47)		13 (28)	21 (51)	
Game cover	Yes	14 (61)	12 (55)	0.02, n.s.	16 (67)	7 (37)	2.68, n.s.	30 (64)	19 (46)	2.05, n.s.
	No	9 (39)	10 (45)		8 (33)	12 (63)		17 (36)	22 (54)	
Game feeding	Yes	20 (87)	17 (77)	0.21, n.s.	19 (79)	10 (53)	2.29, n.s.	39 (83)	27 (66)	2.57, n.s.
	No	3 (13)	5 (23)		5 (21)	9 (47)		8 (17)	14 (34)	
GP shot	Yes	7 (29)	5 (23)	0.02, n.s.	9 (36)	7 (30)	0.01, n.s.	16 (33)	12 (26)	0.16, n.s.
	No	17 (71)	17 (77)		16 (64)	16 (70)		33 (67)	33 (74)	
BH shot	Yes	8 (34)	8 (36)	0.01, n.s.	5 (20)	6 (26)	0.02, n.s.	13 (26)	14 (40)	1.13, n.s.
	No	16 (66)	14 (64)		20 (80)	17 (74)		36 (74)	21 (60)	
Poaching	Yes	11 (48)	11 (50)	0.01, n.s.	14 (58)	8 (42)	0.56, n.s.	25 (53)	19 (46)	0.18, n.s.
	No	12 (52)	11 (50)		10 (42)	11 (58)		22 (47)	22 (54)	
WBC set-aside	Yes	14 (56)	10 (45)	0.54, n.s.	11 (46)	3 (16)	3.09, n.s.	25 (53)	13 (32)	3.29, n.s.
	No	9 (44)	12 (55)		13 (54)	16 (84)		22 (47)	28 (68)	
Access	Yes	21 (91)	19 (86)	0.01, n.s.	19 (79)	14 (74)	0.01, n.s.	40 (83)	33 (80)	0.01, n.s.
	No	2 (9)	3 (14)		5 (21)	5 (26)		8 (17)	8 (20)	
Wildlife conservation	Yes	n/a	10 (40)		n/a	8 (42)		n/a	18 (41)	
	No	n/a	12 (60)		n/a	11 (58)		n/a	23 (59)	
Non-arable CSS	Yes	9 (36)	n/a		13 (54)	n/a		22 (47)	n/a	
	No	14 (64)	n/a		11 (46)	n/a		25 (53)	n/a	