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The benefits of unsprayed cereal crop margins to grey partridges *Perdix perdix* and pheasants *Phasianus colchicus* in Sweden

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Unsprayed cereal crop margins were tested in large-scale field trials during 1991-1994, as part of the Swedish agricultural authorities' nation-wide campaign to reduce pesticide usage. Eleven pairs of farms in central and southern Sweden were chosen. One farm in each pair was sprayed normally (i.e. 90-100% of cereal fields were treated annually with herbicides; insecticides and fungicides were only used after pest and disease thresholds had been exceeded), whilst on the other farm the outer six metres of crop of several cereal fields received no pesticides. In each year, unsprayed crop margins in both autumn- and spring-sown cereals had significantly higher percentages of weed cover. Unsprayed crop margins supported higher densities of non-target arthropods, particularly the non-pest species which are important in the diet of insect-eating gamebird chicks. Significant positive relationships were observed between the densities of these insects and the degree of weed cover. Mean brood sizes and chick survival rates of both grey partridges *Perdix perdix* and pheasants *Phasianus colchicus* were higher on farms with unsprayed crop margins. The effects of omitting herbicide (pesticide) treatments were most dramatic for grey partridges. The treatment, both by itself and mediated through insect density and weed cover, had highly significant effects on brood sizes. There was a significant increase in the mean number of pairs of partridges found in spring on farms with unsprayed cereal crop margins. No similar increase was observed for pheasants. The benefits of unsprayed cereal crop margins to partridges and pheasants are discussed.

Key words: chick survival, grey partridges, insects, pesticides, pheasants, weeds

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The grey partridge *Perdix perdix* is associated with arable field margins and has declined dramatically since the 1950s in several countries (e.g. Potts 1986, Dahlgren 1987). For example, at the turn of the century grey partridges were found as far north in Sweden as Tornedalen (Dahlgren 1987), the river valley that forms Sweden's northeastern border with Finland. There is plenty of anecdotal evidence that partridges were abundant around this time, particularly on the arable plains of central and southern Sweden (e.g. Kolthoff 1913). However, in the 1940s partridge range started to retract southward, and a slow decline in numbers was observed in the central areas of Sweden (Holmström 1947). A drastic decline started in the early 1950s, and by 1986 the national partridge bag was 94% lower than that recorded in 1950 (Fig. 1a). Today the grey partridge is included in Sweden's official Red Data list of threatened and rare species, albeit in the mildest threat category (Ahlen & Tjernberg 1992). A similar dramatic decline, also starting in the early 1950s, has been observed in pheasants (see Fig. 1b). Both pheasants and partridges are released in Sweden, but this is usually on a 'put and take' basis (J. Kindberg, pers. comm.). In 1996, for example, 16,119 pheasants and 4,102 partridges were released over a 128,120-ha hunting area in the southern province of Skåne. Bag returns for the same area at the end of the hunting season were 8,526 pheasants and 1,678 partridges, respectively (Swedish Hunters Association, unpubl. data). The high mortality of released birds is well documented (see e.g. Potts 1986, Hill & Robertson 1988).

Partridge and pheasant chicks are dependent for food on insects, many of which live on arable weeds (Hill 1985, Potts 1986). The use of broad-spectrum herbicides can indirectly reduce food-item insects by removing the host plants on which they depend. Therefore, the modification of pesticide use on cereal crop margins is needed to encourage the growth of certain broad-leaved weeds and their associated insect faunas (Sotherton, Rands & Moreby 1985, Rands & Sotherton 1992). As part of the Swedish agricultural authorities' nation-wide campaign to reduce pesticide usage, large-scale field trials were started in 1991 to examine the benefits of pesticide-free crop margins to the flora and fauna in areas under intensive agriculture in central and southern Sweden. The trials were designed to answer the following questions:

1) Assuming that the omission of herbicide treatments on cereal crop margins results in increased weed densities and cover, would there be corresponding increases in densities of the insects which are associated with arable weeds and are preferred as food by gamebird chicks?
2) Would the provision of insect-rich, weedy cereal crop margins increase the survival of wild gamebird chicks compared to the survival of those on normally sprayed farms?
3) Would an increase in chick survival lead to corresponding increases in adult breeding densities in subsequent years?

The results are compared with those from similar studies elsewhere, and the benefits of this method as a conservation tool for gamebirds are discussed.

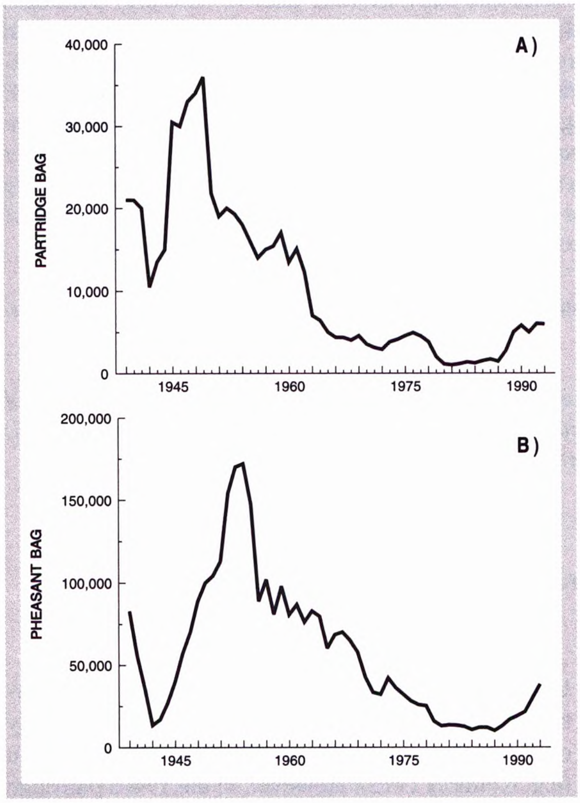

Figure 1. Numbers of grey partridges (A) and pheasants (B) bagged in Sweden during 1939-1993 (source: The Swedish Hunters Association, National Game Census).

Methods and material

Study sites

In 1991, ten pairs of farms in central and southern Sweden were chosen for their similarity in size (mean = 107.1 ha, SE = 8.38), cropping and agricultural practice. An additional pair was included in 1993. Paired farms were a minimum of 5 km and a maximum of 15 km apart and all had previously reported resident populations of partridges. All cereal fields on one farm in each pair ('control' farms) were sprayed normally (i.e. 90-100% of fields were treated annually with herbicides; insecticides and fungicides were usually used after threshold levels had been exceeded; Table 1). During routine applications of herbicides and other pesticides in cereal fields on the experimental farms, spray nozzles on the outer boom of tractor mounted sprayers were turned off so that the outer six metres of crop on one half of the margins in each field received no pesti-

Table 1. Percentages of autumn- and spring-sown cereal fields on study farms and surrounding areas treated annually with insecticides (Ins.), herbicides (Herb.) and fungicides (Fung.) in five different regions of central and southern Sweden during the 1990s. (Source: The National Board of Agriculture, Regional Plant Protection Centres).

	Autumn-sown cereals			Spring-sown cereals		
Region	Ins.[1]	Herb.[2]	Fung.[3]	Ins.[4]	Herb.[5]	Fung.[6]
Uppland	15	90	20	25	90	5
East Götaland	30	100	35	25	90	20
West Götaland	30	100	35	25	90	20
Öland/Gotland	20	90	75	25	90	50
Skåne	80	100	100	50	100	70

[1] Insecticides: Pirimicarb and Pyrethroids (Deltamethrin, Fenvalerate, Lambda cyhalothrin)
[2] Herbicides: Isoproturon, Isoproturon+difluphenikan, Fluroxypyr (autumn treatment); Tribenuron-methyl, MCPA-chlorpyralid-fluroxypyr, Fluroxypyr (spring treatment)
[3] Fungicides: Azoxystrobin, Fenpropimorph+Propiconazole
[4] Insectides: As in [1]
[5] Herbicides: As in [2] (spring treatment).
[6] Fungicides: Propiconazole.

cides. In 1992, where crop rotation allowed, the crop margins in the opposite half of each cereal field received no pesticide. In other cases, crop margins on adjacent fields with cereals were used. In 1993 and 1994 a similar 'rotation' occurred. This within-field, between-year rotation allowed farmers on experimental farms to treat the excess of weeds in the year following an unsprayed margin.

On individual experimental farms the actual positioning of the unsprayed crop margin was determined by the location of pairs of partridges found during the spring survey (see below).

Partridge surveys

In spring and after harvest each year, partridge counts were done using highly trained bird-dogs (pointers, setters and German pointers (Vorsteh)) to find and flush the birds. A network of voluntary dog teams was established in each region to facilitate effective monitoring. The standard method used to monitor partridge pair densities in spring and brood sizes in autumn is by direct observation. Birds are counted at dawn or dusk, in March and over cereal stubbles in autumn (Potts 1986). However, this method is impracticable at very low partridge densities and was inappropriate in the present study because of the time and distances involved in visiting all the farms (the 2,800 km round trip took three weeks to complete).

The spring count established the number of pairs per farm and their locations, and in the case of the experimental farms, where to position the unsprayed crop margins. On each farm, the number of cock and hen pheasants flushed in spring, and the size of pheasant broods flushed in autumn were also recorded. Spring counts were continued in 1995. Autumn brood counts were conducted to estimate the productivity of gamebirds on both experimental and control farms.

Weed assessments

Weeds were assessed in the sprayed and unsprayed margins on experimental farms and on sprayed margins in corresponding cereal crops on control farms. Within each crop margin plot an assessment of the percentage of weed cover was made in 10 quadrats of 0.25 m^2 during the first weeks of July each year.

Arthropod assessments

Vacuum-suction (D-vac) samples were taken from all headland plots at the same time as the weed assessments. In each plot, 10 samples of 0.5 m^2 were taken to extract the small, diurnal epigeal fauna and the crop/weed fauna. Only the results concerning chick-food insects (i.e. Heteroptera and Homoptera (except Aphididae), Curculionidae, Chrysomelidae, and larvae of both Lepidoptera and Tenthredinidae) will be presented here.

Statistical methods

Weed data

Data on the percentage of weed cover displayed a highly skewed distribution and were therefore transformed using the formula $W = Y^{0.25}$, where W is the transformed data and Y is the percentage of weed cover. The effect of herbicide treatment on weed cover was tested using split-plot analysis of variance with year as main plot factor and farm pair, treatment, crop (autumn- or spring-sown cereals) and the treatment*crop interaction as factors (SAS, General

Linear Models procedure). When several fields on one farm were sown with the same type of crop (e.g. winter wheat, spring barley) the same year, the farm average weed cover for that crop was used in the analysis.

Insect data

Before analysis, chick-food insect density data were transformed using a logarithmic transformation ($\log_e(n+0.5)$). The transformed data were analysed using a split-plot model with year as main plot factor and farm pair, treatment, crop (autumn- or spring-sown), and the treatment*crop interaction as factors (SAS, General Linear Models procedure). Weed cover (W) was used as a covariate. As above, when several fields on one farm were sown with the same type of crop the same year, the farm average insect density for that crop was used.

Number of partridge pairs and pheasants in spring, and brood sizes in autumn

In the analyses of the numbers of partridge pairs and adult pheasants in spring (1992-1995), and of brood sizes of both species in autumn (1991-1994), year and farm pair were included in the model in order to account for temporal and spatial variation; year was used as a main plot factor (SAS, General Linear Models procedure). Before analysis, data on the number of partridge pairs and adult pheasants found in spring was transformed using a log transformation ($\text{Log}_e(n+0.5)$). Data from partridge pair and adult pheasant counts in spring 1991 were analysed using a t-test (SAS, T-test procedure) to give the starting situation between farms.

Since the herbicide treatments were assumed to affect the weed cover and, indirectly, the insect density, three analyses were attempted for both partridge and pheasant brood sizes: 1) Year, Farm Pair and Treatment, 2) Year, Farm Pair and Weed Cover, and 3) Year, Farm Pair and Insect density (SAS, General Linear Models procedure). The covariates weed cover and chick-food insect densities were averages for each farm and were transformed as above.

Results

Weed cover

As expected, herbicide treatment reduced percent weed cover by more than 50% in both crop types and in each year of the study; unsprayed crop margins had a significantly higher percentage of weed cover (Table 2). There was significant variation in percent weed cover both between years and between farm pairs (see Table 2). No significant differences were found between crop types, and there was no significant crop*treatment interaction (see Table 2).

Chick-food insect densities

Chick-food insects were found on unsprayed cereal

Table 2. Mean (± S.E.) percentage of weed cover per 0.25 m² in autumn-sown (A) and spring-sown (B) cereal crop margins either treated or untreated with herbicide on 11 pairs of farms in Sweden during 1991-1994. On one farm in each pair cereal crops were fully sprayed with herbicides (Control farm), whilst on the other (Experimental) farm half of the cereal crop margins were unsprayed. The analysis of factors affecting weed cover was conducted on transformed data; see text.

	Experimental farms		Control farms
Year	Unsprayed margins	Sprayed margins	Sprayed margins
A			
1991	24.04 ± 2.32	13.63 ± 0.72	13.98 ± 3.06
1992	19.13 ± 2.69	11.02 ± 2.00	11.79 ± 1.97
1993	28.72 ± 3.05	13.61 ± 1.70	13.08 ± 1.75
1994	20.72 ± 5.40	4.61 ± 0.87	4.83 ± 0.71
B			
1991	32.97 ± 2.20	16.67 ± 0.80	13.80 ± 1.90
1992	18.61 ± 2.40	9.91 ± 2.50	6.21 ± 1.11
1993	24.04 ± 2.01	14.97 ± 1.36	14.23 ± 1.45
1994	17.82 ± 4.94	5.10 ± 1.91	3.90 ± 1.23
Source	df	F	P
Year	3	26.25	0.0001
Farm pair	10	3.88	0.0004
Crop	1	1.49	n.s.
Treatment	1	15.08	0.0003
Crop*treatment	1	0.06	n.s.

Table 3. Mean (± S.E.) densities of insects preferred by gamebird chicks per 0.5 m² found in autumn-sown (A) and spring-sown (B) cereal crop margins either treated or untreated with herbicides on 11 pairs of farms in Sweden during 1991-1994. On one farm in each pair cereal crops were fully sprayed with herbicides (Control farm), whilst on the other (Experimental) farm half of the cereal crop margins were unsprayed. The analysis of factors affecting chick-food insect densities was conducted on transformed data; see text.

	Experimental farms		Control farms
Year	Unsprayed margins	Sprayed margins	Sprayed margins
A			
1991	30.98 ± 13.97	8.00 ± 2.54	5.90 ± 2.64
1992	73.59 ± 31.70	14.50 ± 2.64	11.01 ± 2.11
1993	67.35 ± 14.63	22.41 ± 6.20	11.83 ± 4.79
1994	58.95 ± 15.02	18.71 ± 4.57	14.44 ± 5.02
B			
1991	25.72 ± 4.45	12.77 ± 2.14	9.79 ± 1.82
1992	56.53 ± 16.93	32.30 ± 18.01	19.60 ± 11.94
1993	40.30 ± 8.58	10.40 ± 2.85	16.40 ± 3.36
1994	35.16 ± 8.90	23.78 ± 4.18	21.23 ± 5.96
Source	df	F	P
Year	3	7.49	0.0003
Farm pair	10	5.99	0.0001
Crop	1	0.58	n.s.
Treatment	1	14.24	0.0004
Crop*treatment	1	0.89	n.s.
Weed cover	1	5.35	0.0242

field margins at mean densities twice as great as those found on margins treated with herbicides (Table 3). Chick-food insect density was significantly different between years and between farm pairs (see Table 3). The treatment effect was also highly significant. Even after adjusting for other effects in the model, the amount of weed cover significantly affected chick-food insect density, i.e. there were higher densities of these insects on unsprayed cereal crop margins (see Table 3). No differences were found between crop types, and there was no significant crop*treatment interaction (see Table 3).

Significant positive relationships were found between the densities of chick-food insects and the degree of weed cover in both types of cereals (except spring cereals 1994), and in each year of the study (Table 4).

Partridge surveys

During 1991-1995 the highest densities of partridge pairs in spring were found on both experimental and control farms on the Baltic islands of Öland and Gotland (Fig. 2). Pair densities were much lower on the mainland and rarely exceeded an average of 2/km² throughout the period.

Annual variation in mean number of partridge pairs was not significant but, as shown above, spatial variation (i.e. geographical location of farm pairs) was highly significant (Table 5a). In spring 1991, prior to the establishment of unsprayed cereal field margins, there was no significant difference between the mean number of pairs found on experimental farms (2.11 ± 0.46) compared with control farms (1.94 ± 0.43), (t_{16} = -0.26, n.s.). However, significantly greater mean numbers of partridge pairs were found on experimental farms in the years following the introduction of unsprayed cereal crop margins (Fig. 3).

Mean partridge brood size was significantly larger on experimental farms (8.80 ± 0.63) than on control

Table 4. Correlation coefficients from the relationships between the densities of insects preferred by gamebird chicks and the degree of weed cover found in herbicide treated and untreated margins of autumn- and spring-sown cereal crops on 11 pairs of farms in Sweden during 1991-1994. The analysis was conducted on transformed data, see text. *** = P < 0.001, * = P < 0.05, n.s. = not significant.

	Autumn-sown cereals			Spring-sown cereals		
Year	r	P	df	r	P	df
1991	0.80	***	14	0.43	*	33
1992	0.66	***	30	0.42	*	27
1993	0.85	***	27	0.52	*	20
1994	0.76	***	33	0.36	n.s.	27

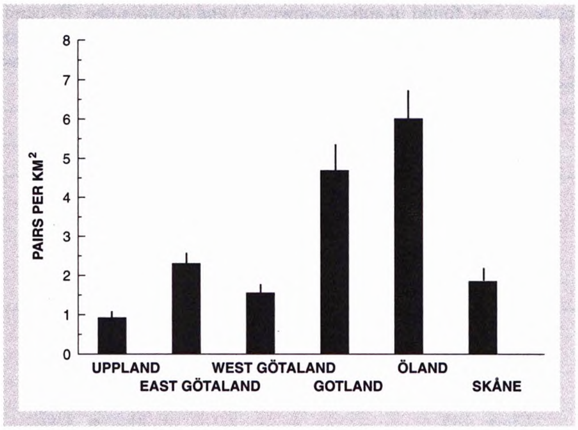

Figure 2. Mean (+ S.E.) densities (per km^2) of grey partridge pairs found in spring on farms in six regions of central and southern Sweden during 1991-1995.

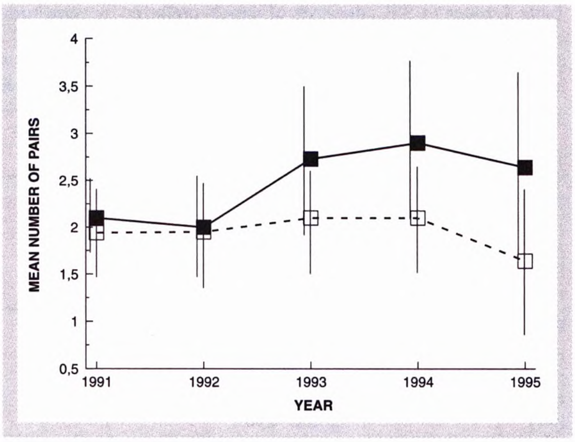

Figure 3. Mean (± S.E.) number of grey partridge pairs found in spring on farms with unsprayed cereal crop margins (■) and farms with herbicide treated cereal crop margins (□) in central and southern Sweden during 1991-1995. Unsprayed cereal crop margins were established in the summer of 1991. For test statistics, see Table 5a.

farms (6.89 ± 0.53, $P < 0.05$, Student-Newman-Keul's multiple range test). Brood size was significantly affected by insect density and percent weed cover (Table 6a). Brood sizes also displayed a significant variation between farm pairs (see Table 6a).

Chick survival rates ($CSR = 3.665x^{1.293}$, where x is the geometric mean brood size (Potts 1986)) were correspondingly higher on experimental farms in each year of the study (Fig. 4a).

Pheasant surveys

The highest densities of cock and hen pheasants in spring were found on farms in the southernmost province of Skåne (Fig. 5). In all other localities

Table 5. Factors affecting the mean numbers of pairs of grey partridges (A) and adult pheasants (B) found in spring on 11 pairs of farms in central and southern Sweden during 1992-1995. On one farm in each pair cereal crops were fully sprayed with herbicides, whilst on the other farm half the cereal crop margins were unsprayed. The analysis was conducted on transformed data; see text.

Factor	df	F	P
A			
Year	3	1.14	n.s.
Farm pair	10	9.29	0.0001
Treatment	1	9.75	0.0040
Year*Farm pair	29	0.67	n.s.
Year*Treatment	3	0.89	n.s.
Farm pair*Treatment	10	1.59	n.s.
B			
Year	3	2.53	n.s.
Farm pair	10	7.38	0.0001
Treatment	1	1.74	n.s.
Year*Farm pair	29	2.79	0.0037
Year*Treatment	3	0.8	n.s.
Farm pair*Treatment	10	1.44	n.s.

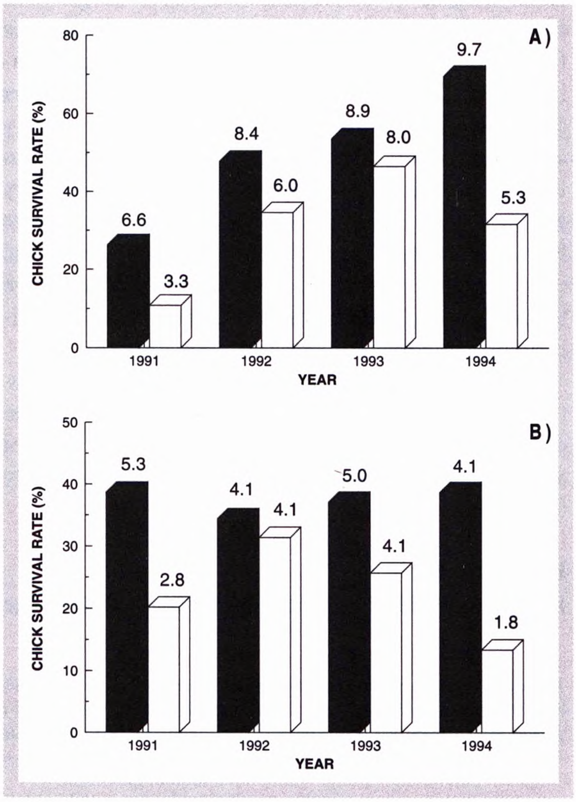

Figure 4. Survival rates of grey partridge (A) and pheasant (B) chicks found on farms with herbicide treated (□) and unsprayed (■) cereal crop margins during 1991-1994. Figures above columns give mean brood sizes for treatment and year, respectively. See text, for further details.

Table 6. Factors (including herbicide treatment, chick-food insect density and weed cover) affecting the brood sizes of grey partridges (A) and pheasants (B) found in autumn on 11 pairs of farms in central and southern Sweden during 1991-1994. On one farm in each pair cereal crops were fully sprayed with herbicides, whilst on the other farm cereal crop margins were unsprayed. Mean brood sizes for partridges and pheasants are given in Figs. 4a & b, respectively.

		A) Partridge Broods		B) Pheasant Broods	
Factor	df	F	P	F	P
Year	3	1.83	n.s.	2.24	n.s.
Farm pair	10	2.59	0.0178	4.33	0.0005
Year*Farm pair	24	1.18	n.s.	0.79	n.s.
Treatment	1	12.42	0.0012	0.72	n.s.
Year	3	0.46	n.s.	2.01	n.s.
Farm pair	10	3.72	0.0017	3.91	0.0012
Year*Farm pair	24	1.43	n.s.	0.78	n.s.
Insect density	1	14.26	0.0006	0.20	n.s.
Year	3	3.19	0.0352	1.84	n.s.
Farm pair	10	2.82	0.0108	3.94	0.0011
Year*Farm pair	24	1.4	n.s.	0.77	n.s.
Weed cover	1	13.65	0.0007	0	n.s.

mean spring densities of both cock and hen pheasants were generally less than one per km^2 (see Fig. 5). In spring 1991, prior to the establishment of unsprayed cereal field margins, there was no significant difference between the mean number of adult pheasants found on experimental farms (4.78 ± 2.20) compared with control farms (4.78 ± 3.00), ($t_{16} = 0.00$, n.s.). Following the establishment of unsprayed cereal margins, total numbers of adult pheasants in spring were mainly affected by farm pair, although the year*farm pair interaction was also highly significant (see Table 5b).

Mean pheasant brood sizes were significantly different between farm pairs. No significant treatment effects were observed in this model, and neither year nor the year*farm pair interaction were significant (see Table 6b). Neither insect densities nor weed cover had significant effects on pheasant brood size (see Table 6b). However, in a simpler General Linear Model - disregarding farm pair, but including year, treatment and the year*treatment interaction - treatment was found to significantly affect pheasant brood size ($F = 6.15$, df = 1, $P = 0.0158$).

Mean brood size was significantly larger on experimental farms (4.83 ± 0.45) than on control farms (3.36 ± 0.33, $P < 0.05$, Student-Newman-Keul's multiple range test). Pheasant chick survival rates ($CSR = 3.665\ (1.5x)^{1.293}$, based on the formula for partridges (Potts 1986) and adjusted for the average size of pheasant broods at hatching (N. Aebischer, pers. comm.), were correspondingly higher in each year of the study (see Fig. 4b).

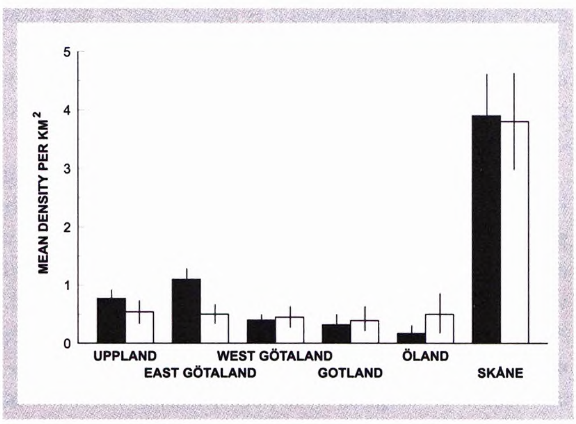

Figure 5. Mean (± S.E.) densities (per km^2) of cock (■) and hen (□) pheasants found in spring on farms in six regions of central and southern Sweden between 1991-1995.

Discussion

Omission of herbicide sprays on the outer six metres of cereal crop margins during routine spraying operations resulted in increases in the degree of weed cover and in the densities of preferred chick-food insects. The response to this increase in food resources was dramatic, especially for partridges; brood sizes were on average 33% larger, and hence chick survival was greater, where broods had access to food-rich unsprayed cereal crop margins. The above results, particularly those concerning partridges, confirm those from earlier investigations demonstrating the value of selectively-sprayed cereal crop margins for partridge and pheasant chick survival (see e.g. Rands 1985, Sotherton, Boatman & Rands 1989, Rands & Sotherton 1992). Furthermore, the present study shows that unsprayed cereal crop margins can significantly increase mean numbers of breeding pairs of partridges.

Of the chick-food insects, the groups which responded best to the unsprayed cereal crop margins were the Heteroptera and, to a lesser extent, the Homoptera (P.A. Chiverton, unpubl. data). Similar effects on these groups have been observed in earlier studies with both selectively-sprayed and unsprayed cereal crop margins (see e.g. Rands 1985, Chiverton & Sotherton 1991, Moreby & Aebischer 1992, de Snoo 1995). As a group, Heteroptera and Homoptera have been positively correlated with survival rates of partridge chicks both in the U.K. (Aebischer 1989) and Poland (Panek 1992). The latter author also found higher average numbers of plant bugs (Heteroptera) in small fields compared to large fields (Panek 1997, see below). Furthermore, Hill (1985) found that Heteroptera and Homoptera together with sawfly and Lepidoptera larvae were, in terms of dry weight, the most important arthropods in the diet of pheasant chicks. Together these four categories collectively constituted 58% of the diet (Hill 1985).

The increases in mean brood sizes observed in the present study were of approximately the same magnitude as those found in similar experiments and observations elsewhere. In Poland for example, where up to 70% of crop area was not sprayed, the mean brood size of grey partridges was 9.3 (Panek 1992) compared to 4.8 on intensively farmed arable land in the U.K. (Sotherton & Robertson 1990); the latter increased to 7.4 in insect-rich, selectively-sprayed, weedy cereal crop margins (Sotherton & Robertson 1990). Pheasant brood sizes increased from 2.8 in fully-sprayed cereal fields to 4.9 in fields with selectively-sprayed crop margins (Sotherton & Robertson 1990). The corresponding figures for pheasants obtained in the present study are remarkably similar, i.e. 3.4 on farms with fully sprayed, and 4.8 on farms with unsprayed crop margins, respectively.

Unfortunately, there are very few references in the (Swedish) literature with which to compare the partridge spring pair density data presented above. Dahlgren, Frylestam & Göransson (1983) found a mean of 1.89 ± 0.85 pairs/km^2 on seven estates in southern Sweden during 1980-1982. These authors surveyed pairs of partridges by direct observation, a method which may have underestimated actual densities. Nevertheless, the density is very similar to that found in the same area during the present study (1.85 ± 0.34), possibly indicating that breeding densities in southern Sweden at least have remained fairly stable at this low level during the last decade. Using dogs, E. Ringaby (pers. comm.) has surveyed partridge pair densities over a 10-km^2 area on the northeastern side of the Baltic island of Öland since 1987. He found a mean pair density of 2.24 ± 0.28 per km^2 over a 10-year period. Although relatively low compared to the average of 6.01 pairs found (in southwestern Öland) in the present study, Ringaby's results confirm that Öland is a stronghold for partridge populations in Sweden. This may partly be explained by the fact that arable fields on many parts of the island are characterised by their long narrow shape and that the majority are surrounded by dry stone walls. The vegetation (e.g. dead grass and shrubs) found in spring on either side of the base of these walls should constitute ideal nesting habitat for grey partridges (*cf.* Rands 1986). Thus the area of good quality nesting habitat per km^2 is much higher compared to that on the arable plains on the mainland, where field sizes have increased dramatically over the last 50 years as a result of agricultural intensification (Ihse 1995). In Poland, Panek (1997) found average spring pair densities of 1.60/100 ha in arable areas with large fields (10-50 ha) compared to 6.00 pairs/100 ha in areas with small fields (1-10 ha).

Potts (1996) has recently high-lighted the value of traditional grass leys for game and farmland wildlife; leys provide ideal habitats for preferred chick-food insects during the summer and weedy stubble for birds to feed on through the winter. Large decreases in the use of undersowing have been indicated as a partial reason for the decline of partridge densities in several study areas in the U.K. (Potts 1996). Considering the above-mentioned national decline in Swedish partridge populations it is interesting to note that the total area of grass leys established by undersowing cereals in Sweden has not changed significantly over the last 30-40 years (M. Tuvesson, pers. comm.).

The number of adult pheasants observed in spring in the present study was mainly affected by farm pair and the year*farm pair interaction. This simply means that there was a large temporal and spatial variation in the numbers of adult pheasants found. Numbers in the southern province of Skåne, where mean spring densities were highest, actually decreased from an average of 17.5 per farm in 1991 to 5.3 in 1995. The reasons for this decline are not known.

Interestingly, partridge pairs were invariably found in almost the exact same locations on individual farms in each year of the study. Assuming the majority of these pairs would attempt to nest in the immediate vicinity of where they were found (see Potts 1986), this strongly suggests that once these favoured sites were occupied any excess birds were either forced off the farm by the dominant pairs, or fell to predation. The latter may have occurred on coveys during the winter or soon after pair formation in the early spring. Whilst evidence of predation was observed on several farms in each year of the study, this was not quantified. However, Tapper, Potts & Brockless (1996) have clearly demonstrated a 2.6-fold difference in partridge breeding density between sites with and without predation control.

Any strategy aimed at reversing the decline of partridge and pheasant populations in Sweden and elsewhere must include all three conservation tools mentioned above, i.e. i) reduced pesticide use on crop margins to increase densities of chick-food insects; ii) habitat management to improve the availability of suitable nesting and overwintering sites (grass leys and EU set-aside options should be investigated in this respect); and iii) predation control to protect the products of i) and ii).

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