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MANIPULATING PESTICIDE USE TO INCREASE THE PRODUCTION OF WILD GAME BIRDS IN BRITAIN

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Abstract: We describe a management technique whereby the adverse effects of pesticides on game-bird chick production were alleviated following selective use or selective avoidance of pesticides on the edges of cereal crops. This technique (known as Conservation Headlands) provided increased amounts of food resources necessary for young gray partridge (*Perdix perdix*) and ring-necked pheasant (*Phasianus colchicus*) chicks. The use of Conservation Headlands has consistently increased average numbers of chicks per brood of both species via increases in the densities of arthropods and weed plants. These findings are discussed in the context of the other prerequisites of wild game-bird production in the UK and how these may be altered by recent Government policies to reduce cereal surpluses.

Key words: Britain, chick foods, Conservation Headlands, gray partridge, indirect effects, pesticides, ring-necked pheasant.

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In 1968, studies were initiated to identify factors contributing to an observed 80% decline over 40 years of the gray partridge in the UK (Potts 1980, 1986). This led to research begun in 1984 on devising management strategies to deal with the causes of poor levels of wild game-bird production on intensively farmed arable land.

Earlier studies (Blank et al. 1967, Potts 1980) identified the key factor causing changes in a gray partridge population in the southern UK as chick mortality, and linked national declines with poor chick survival. Also, chick survival was shown to be linked to availability of sufficient quantities of preferred insects, essential in the diet of young chicks of both gray partridge (Southwood and Cross 1969, Potts 1986) and pheasant (Hill 1985). It has been suggested that increasingly intensive production over the last 40 years has resulted in low densities of preferred insects in cereal fields (Potts 1986, Rands et al. 1988). Use of pesticides (insecticides, herbicides, and fungicides) appeared to be a major contributory factor in reducing populations of preferred insects.

Green (1984) listed preferred food items of young partridge chicks in the UK. These include Coleoptera (Chrysomelidae, small diurnal Carabidae, and Curculionidae), larval forms of Lepidoptera and Tenthredinidae (especially species of the genus *Dolerus*), and many members of the Heteroptera (especially species of the genus *Lygocoris*). Many preferred insects were relatively abundant at the edges of cereal fields where gray partridge broods foraged (Green 1984).

The use of both insecticides and insecticidal fungicides can detrimentally affect these nontarget species (Vickerman 1977, Vickerman and Sunderland 1977, Vickerman and Sotherton 1983, Sotherton et al. 1987, Sotherton and Moreby 1988), as can herbicides. The use of herbicides has probably been the most important factor because they limit cereal field weeds, the host plants of many phytophagous chick-food insects (Southwood and Cross 1969, Vickerman 1974, Sotherton 1982). Approximately 60% of preferred chick-food insects are phytophagous species feeding on weeds of the genera *Polygonum*, *Fallopia*, *Chenopodium*, *Sinapis*, and *Matricaria*. Thus pesticides disrupt the food chains of game-bird chicks both directly (insecticides) and indirectly (herbicides).

The dilemma has been to devise practical management options whereby cereal farmers could continue to maintain high levels of crop production while ameliorating some of the observed effects of pesticides on farmland wildlife. One possible solution was selectively sprayed cereal crop margins or Conservation Headlands. In this management system, the outermost section of the spray boom (in most cases, the outermost 6 m depending on spray-boom width) was either switched off when spraying around crop edges or "headlands" to avoid particular chemicals at certain crucial times of the year, or the headlands were sprayed separately with more selective compounds, approved following field screening for selectivity. The interior of the field was sprayed with the usual complement of pesticides, and only the outermost crop edge (usually calculated at 6% of total field area) received lower pesticide inputs.

Results of selective use of pesticides have been published in part elsewhere (Rands 1985, 1986, Sotherton et al. 1985). In this paper we update some results and summarize implications, progress, and the future of this work, including prospects for increasing food resources for wild game birds despite current and pending attempts to reduce surplus grain production through land-use changes.

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SITES AND METHODS

From 1983 to 1986 field-scale experiments were carried out on an 11 km^2 mixed arable and livestock farm in Hampshire, southern UK. Several large blocks (100 ha) of cereal fields on the principal study farm were sprayed either entirely or except for the outermost 6 m in a randomized block design. Use of pesticide on this outermost strip varied slightly between years as the term "selective spraying" was refined, but in all cases the aim was to avoid use of insecticidal chemicals and broadleaf herbicides. In this way blocks of up to 12 fields had their headland pesticide regime manipulated to not seriously reduce yield, cause problems with harvesting or grain quality, or increase management effort on the farm but which benefited wild game production so that these techniques could be widely adopted by farmers. A summary of the current set of guidelines updated from Boatman and Sotherton (1988) are given in Table 1.

Similarly, from 1984 to 1986 paired blocks of cereal fields were set up on farms in eastern UK counties. In addition, from 1986 to 1990 pooled game-bird data from within- and between-farm comparisons were available from eastern counties. More rigorous pairings of replicated blocks of cereal fields with different headland pesticide regimes on study areas were no longer available on farms where estate owners abandoned the experimental approach in favor of a more widespread, farm-scale use of Conservation Headlands. Data derived from these farms were therefore based on less rigorous experimental designs.

In all experiments, measures of game-bird breeding success (rates of chick survival and/or mean brood size in autumn) were compared among broods with and without access to Conservation Headlands in brood rearing areas.

Chick-food Insects and Broadleaf Weeds

Details of experimental designs and methods used in 1983 and 1986 to quantify effects of adjusting pesticide inputs on cereal field headlands on the densities of preferred chick-food items have been published elsewhere (Sotherton et al. 1985, Rands 1985). Methods of measuring changes in weed flora are described elsewhere (Boatman 1988). However, on all occasions weed densities were measured. Where possible additional

Table 1. A summary of guidelines for selective use of pesticides on Conservation Headlands in UK cereal fields, 1992.

	Autumn spraying	Spring spraying
Insecticides	Yes (avoiding drift)	No (only up until 15 March)
Fungicides	Yes	Yes (except compounds containing pyrazophos)
Growth regulators	Yes	Yes
Herbicides		
a) Grass weeds	Yes[a] (but only those compounds approved for use; i.e., avoid broad-spectrum residual products)[b]	
b) Broadleaf weeds	No[a] (except those compounds approved for use against specific problem weeds; eg., *Galium aparine*)	

[a]These guidelines refer to both spring and autumn spraying.
[b]Tri-allate, dichlofop-methyl, difenzoquat, flamprop-m-isopropyl, fenoxaprop-ethyl, tralkoxydim.

measures such as species diversity, weed biomass, and percentage weed cover were also recorded. For more recent experiments to measure insect abundance the following methodologies were used.

Experimental Design

Spring Wheat 1988.—One headland of a field of spring-sown wheat was divided into 8 plots (100 x 9 m). In April, herbicides were excluded from alternate plots. All plots were sprayed with fungicides and plant growth regulators (straw stiffeners and shorteners) and received equal amounts of fertilizer. As the adjacent field boundary type and its aspect were the same for all plots, only the herbicide application was withheld from the Conservation Headland plots in accordance with guidelines for herbicide use on spring-sown crops. Selective graminicides were not needed on this crop.

Before herbicide application, and on 5 dates afterward, insects were sampled using a vacuum insect sampler. On each sampling date and on each plot per treatment, 5 samples of 0.5 m^2 were taken.

Winter Wheat 1988.—On 1 block of land on the principal study farm, headlands were fully sprayed, whereas all other cereal fields on the farm had their headlands managed according to guidelines for Conservation Headlands. Headlands within the fully sprayed block were chosen and paired up with headlands in fields with Conservation Headlands, so that their aspect and adjacent field boundaries were the same. Nine pairs of winter wheat headlands were chosen and sampled once in early June with a vacuum sampler again taking 5 samples of 0.5 m^2 per headland.

Game Birds

Breeding success of gray partridges and pheasants was measured by counting numbers of juvenile and adult birds on cereal stubble after harvest and calculating mean brood size (excluding zeros). Gray partridge censuses began in 1983 and pheasant counts in 1984. Radio-tagging was also used to track individual broods in 1984 (partridge) and 1988 (pheasant). Backpack radios were fitted to sitting females on the nest immediately prior to hatching. Location of broods was estimated by triangulation 3 times per day and once at night to record roosting position. Data gathered using radio-tagging for gray partridges included chick survival per brood to 21 days old, home range size (minimum polygon area), the proportion of home range including the headland area, and distance between successive roost sites. One estimate of mean survival of pheasant chicks to 10 days old was also obtained. In addition, chick fecal samples were collected from roost sites of both species, and insect fragments were counted and identified (Moreby 1988). Multiple stepwise regression was used to identify which insect taxa were responsible for observed variations in chick survival rates. Percentage data were converted by the arc sin transformation. Further details of the experimental design may be found elsewhere (Rands 1985), as well as methodologies used to assess weed density and details regarding radio-tagging (Rands 1985, 1986, Sotherton et al. 1985, Hill and Robertson 1988). Long-term effects of pesticide use on gray partridge demography were measured by recording annual spring breeding densities (expressed as pairs per km^2) on the main study farm in Hampshire.

RESULTS and DISCUSSION

Broadleaf Weeds

Effects of the selective exclusion of herbicides on broadleaf weeds led to as much as a 10-fold increase in total broadleaf weed density where herbicide inputs were reduced, compared to those areas that were fully sprayed. Species diversity, weed biomass, and percentage weed cover all increased significantly in the absence of broadleaf weed herbicides. Data for 1983-88 appear in detail elsewhere (for 1983 and 1984, Sotherton et al. 1985; for 1985 and 1986, Boatman 1988; and for 1988, Sotherton 1991, Chiverton and Sotherton 1991).

Insects

Some insect data showing differences between cereal field headland pesticide spraying regimes have been published elsewhere (Sotherton et al. 1985, Rands 1986). In these trials, conducted in 1983 and 1984, 2- and 3-fold increases in chick-food insect densities on Conservation Headlands were obtained compared to headlands that were fully sprayed. Greater differences between treatments were found for sedentary, weed-feeding species.

In 1988 in spring-sown wheat, the absence of broadleaf weed herbicides resulted in increases in chick-food insect groups. Mean pretreatment densities were very similar and did not differ significantly among plots; in most instances numbers were very low. After treatment, significantly higher densities of Heteroptera ($P < 0.02$; mostly

Table 2. Mean densities/0.5 m^2 (±1 SE) of nontarget, beneficial arthropods found by vacuum-suction sampling of headland plots of spring wheat before and after (average of 5 posttreatment assessments) treatment with a herbicide mixture or remaining untreated, Hampshire, 1988 (analysis conducted on transformed data log 10 [n+1]).

	Pretreatment			Posttreatment		
Chick-food item	With herbicide	Without herbicide	t_6	With herbicide	Without herbicide	t_6
Total chick-food items	2.60 ±0.36	2.80 ±0.51	0.28	29.90 ±4.09	68.60 ±11.67	3.13[a]
Tenthredinidae larvae	0.20 ±0.13	0.10 ±0.06	1.06	1.80 ±0.27	2.00 ±0.44	0.43
Lepidoptera larvae	0.0	0.0		0.30 ±0.05	0.60 ±0.15	0.22
Chrysomelidae	1.10 ±0.33	1.10 ±0.53	0.04	4.00 ±0.38	9.90 ±3.77	1.57
Heteroptera	0.10 ±0.10	0.10 ±0.10	0.01	10.40 ±1.97	36.00 ±6.73	3.65[b]

[a] $P < 0.05$.
[b] $P < 0.02$.

Calocoris spp.) were found on untreated plots (Table 2).

Other chick-food insect groups such as the larvae of Lepidoptera and Tenthredinidae were generally found in higher numbers in untreated plots. However, these groups were found in low numbers and did not differ significantly between treatments plots (Table 2). Chrysomelidae were found on untreated plots at mean densities twice as great as those found on areas treated with herbicides, although these differences were not significant (Table 2).

In the winter wheat trial, average insect densities were over twice as great in Conservation Headlands compared to matched headlands that were fully sprayed ($P < 0.02$; Table 3). The greatest differences were found within Tenthredinidae larvae, but again densities were very low. It is worth noting that in both experiments conducted in 1988 no insecticides were used to control aphid pests during the spring/summer period. If they had been used, chick-food insect densities on sprayed headlands would have been severely reduced, exacerbating between-treatment availabilities of these vital chick-food insects to foraging chicks.

Game Birds

Brood Counts.—In replicated experiments conducted using either the randomized block design (Hampshire) or paired block design (eastern counties), the increased provision of insect resources in cereal fields surrounded by selectively sprayed headlands led, in most cases, to significantly

Table 3. Mean densities/0.5 m^2 (±1 SE) of a between-field comparison of chick-food insect groups collected by vacuum suction sampling on matched pairs of winter wheat headlands either fully sprayed with the normal complement of pesticides or receiving pesticide applications stipulated under guidelines for Conservation Headlands, Hampshire, 1988.

	Conservation Headlands $n = 9$	Fully sprayed headlands $n = 9$	t_8	P
Total chick-food items	37.40 + 3.40	15.60 + 2.20	3.2	<0.02
Tenthredinidae larvae	0.60 + 0.08	0.09 + 0.02	2.0	NS
Chrysomelidae	1.70 + 0.30	0.40 + 0.02	1.6	NS
Hemiptera (Heteroptera and selected Homopterans)	34.70 + 3.10	14.80 + 2.10	3.4	<0.01
Carabidae	0.30 + 0.03	0.20 + 0.04	0.8	NS

Table 4. Mean gray partridge brood sizes (±1 SE) on blocks of cereal fields with sprayed and selectively sprayed headlands in Hampshire and eastern UK (from Rands 1985, 1986, Sotherton et al. 1989).

		Gray partridge mean (±1 SE) brood size			Ring-necked pheasant mean (±1 SE) brood size		
Study area	Year	Sprayed headlands[a] (*n*)	Selectively sprayed headlands (*n*)	*P*	Sprayed headlands (*n*)	Selectively sprayed headlands (*n*)	*P*
Principal	1983	4.7 ± 1.1 (39)	8.4 ± 1.2 (29)	<0.010			
study	1984	7.5 ± 0.8 (34)	10.0 ± 0.6 (34)	<0.010	3.2 ± 0.5 (18)	6.9 ± 0.5 (29)	<0.001
farm	1985	3.3 ± 0.7 (9)	5.7 ± 0.8 (14)	<0.050	3.0 ± 1.0 (3)	4.6 ± 0.6 (8)	<0.050
(Hampshire)[b]	1986	5.9 ± 1.6 (17)	6.2 ± 1.0 (21)	NS	2.0 ± 0.5 (8)	5.9 ± 0.7 (10)	<0.010
	1984	4.7 ± 0.4 (71)	7.8 ± 0.6 (57)	<0.001			
Eastern	1985	2.7 ± 0.4 (19)	4.0 ± 0.7 (19)	<0.050	2.6 ± 0.3 (30)	3.7 ± 0.4 (35)	<0.010
UK[c]	1986	4.8 ± 0.6 (32)	8.7 ± 1.5 (6)	<0.001	3.4 ± 0.6 (14)	3.5 ± 0.7 (6)	NS

[a]Sprayed headlands = areas of crop edge receiving full pesticide inputs; selectively sprayed headlands = areas of crop edge only receiving selective pesticides approved under Conservation Headlands guidelines.
[b]Pooled data from each block/treatment on the farm.
[c]Pooled data from each block/treatment/farm.

greater mean brood sizes in gray partridges and pheasants (Table 4), compared to those in equivalent blocks of cereal fields that had been fully sprayed.

In 1986 it appeared that fundamental changes in the use of newly permitted herbicides within guidelines for pesticide use on Conservation Headlands were responsible for the small between-treatment differences in mean brood size in Hampshire. As a result, these newly-permitted herbicides reduced weed densities below that experienced in previous seasons. At the same time, spring weed control in fully sprayed blocks did not occur because of excessively wet spring weather. This resulted in those fully sprayed headlands becoming excessively weedy compared to previous years. The within-farm, within-season differential in weed density was not as great as in previous experimental years, which led to decreased differences in brood sizes. As a result of these experiences, such residual, broad-spectrum herbicides are now specifically excluded from the guidelines (Table 1). From 1987 to 1990 in less controlled experimental designs, brood sizes of both species were consistently higher where birds could exploit the resources of Conservation Headlands (Table 5).

In similar experiments in Sweden in 1991, mean brood size and chick survival rates of gray partridges were higher on farms employing Con-

Table 5. Between-farm comparisons on farms in eastern UK of average mean brood sizes (chicks/brood) of gray partridges and pheasants (1987–90) of selectively sprayed headlands with those fully sprayed (no. of farms).

	Gray partridge		Ring-necked pheasant	
Year	Sprayed headlands[a]	Selectively sprayed headlands	Sprayed headlands	Selectively sprayed headlands
1987	4.0 (7)	7.1 (8)	2.2 (4)	3.2 (4)
1988	4.4 (7)	6.2 (8)	no data	
1989	5.1 (9)	7.3 (11)	3.0 (9)	3.2 (11)
1990	4.1 (15)	4.4 (10)	3.0 (3)	3.0 (5)

[a]Sprayed headlands = areas of crop edge receiving full pesticide inputs; selectively sprayed headlands = areas of crop edge only receiving selective pesticides approved under Conservation Headlands guidelines.

servation Headlands (4.6 ± 1.4 chicks/brood; n = 10 farms; 26.3% chick survival rate [CSR]) compared to farms that were fully sprayed (2.3 ± 1.5; n = 4; 10.8% CSR) but these differences were not significant. Similar trends were found for pheasants on farms with Conservation Headlands (4.1 ± 1.4 chicks/brood; n = 7; 38.7% CSR) compared to farms that were fully sprayed (2.5 ± 1.3; n = 6; 20.2% CSR), but again differences were not significant (P. A. Chiverton, pers. commun.).

When data were expressed as percentage chick survival using the formula of Potts (1986), rates of survival were always higher on farms in the eastern UK employing Conservation Headlands (Table 6, Fig. 1). Potts also calculated the minimum annual rate of chick survival necessary for a population of partridges to maintain itself as 30%. During 8 years of monitoring, in only 1 year was this minimum rate achieved on the fully sprayed farms. In contrast, on farms using Conservation Headlands, in 5 of 8 years chick survival rates exceeded this minimum and in some cases reached the rate of survival found in the UK in the prepesticide era (Potts 1986).

Table 6. Gray partridge chick survival rate on selected farms in East Anglia, comparing Conservation Headlands with fully sprayed areas. Chick survivals are percentages with 1 SE.

Year	No. of farms	Fully sprayed	Conservation Headlands
1984	8	27.0 ± 0.8	52.0 ± 1.9
1985	8	13.2 ± 1.1	22.0 ± 2.3
1986	9	27.8 ± 1.9	59.9 ± 6.2
1987	11	21.9 ± 1.9	46.1 ± 3.2
1988	12	24.9 ± 4.2	38.7 ± 6.1
1989	9	30.2 ± 2.5	48.0 ± 7.5
1990	20	22.8 ± 2.2	24.6 ± 3.7
1991	18	18.4 ± 1.1	21.2 ± 1.9
Average	12	23.3 ± 1.9	39.1 ± 5.3
Percentage of years above 30% minimum recovery rate		12.5	62.5

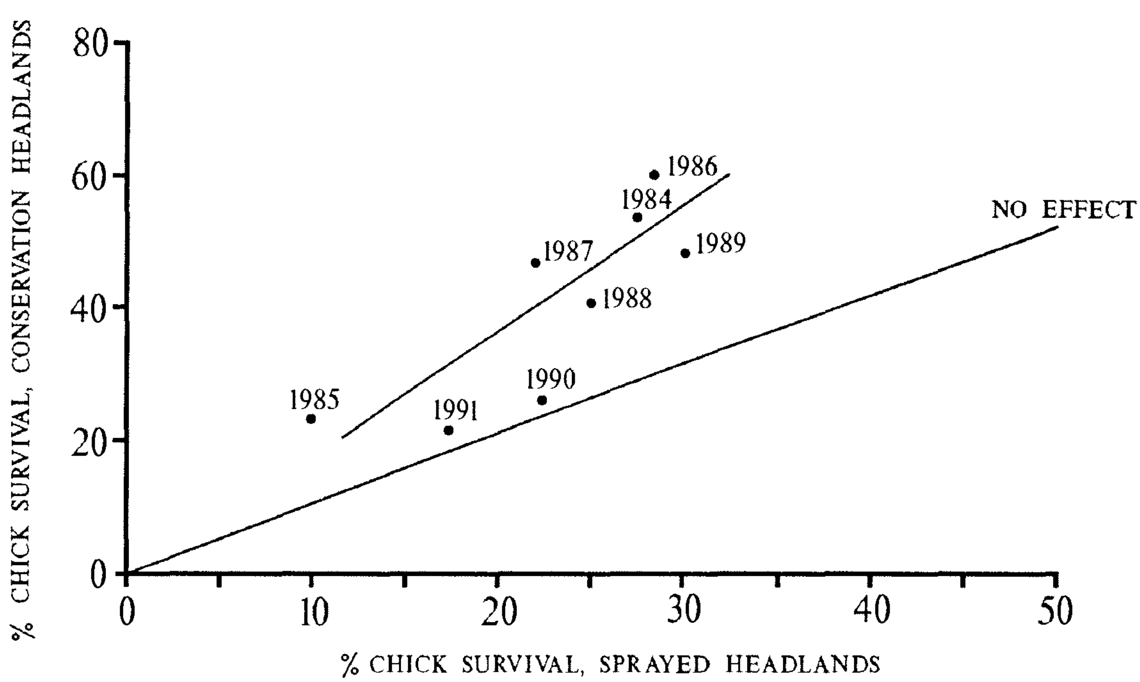

Fig. 1. Effect of Conservation Headlands on gray partridge chick survival in the eastern UK (1984-91).

Table 7. Mean survival, movement, and home range size (±SE) of 7 radio-tagged gray partridge broods in the sprayed and selectively sprayed blocks (spring barley fields only), principal study farm, Hampshire, 1984 (from Rands 1986).

	Fully sprayed headlands (4 broods; 40 chicks)	Selectively sprayed headlands (3 broods; 43 chicks)
Survival to 21 days (%)	59.6 ± 12.0	97.7 ± 2.3 <0.05
Mean distance between successive roost sites (m)	102.3 ± 14.6	43.5 ± 1.7 <0.05
Home range size (ha; max. polygon area)	2.2 ± 0.8	0.8 ± 0.5 NS
Proportion of home range including headland (%)	12.6 ± 3.8	26.6 ± 0.8 <0.05

Radio-tagging.—Gray partridge broods feeding in spring barley fields with selectively sprayed headlands had higher survival than broods in fully sprayed fields. Broods moved less between successive roost sites, and their home ranges were smaller where they included areas of Conservation Headlands. The proportion of headland within the home range also increased where the home range included Conservation Headlands (Table 7). Chick survival to 21 days has previously been shown to be significantly negatively correlated to mean distance between successive roost sites (r = -0.60, 15 df, $P < 0.01$; Rands 1986).

In preliminary studies of radio-tagged female pheasants conducted in 1988, mean chick survival rate to 10 days old of broods reared close to Conservation Headlands was 39% (mean of 7 broods). In equivalent fully sprayed areas, mean chick survival rate to this age was only 25% (mean of 3 broods; Coates 1988), but differences were not significant.

Chick Fecal Analysis.—Following a multiple stepwise regression, there was a significant positive relationship between percentage gray partridge chick survival per brood to 21 days old and the proportion (percentage) of Tenthredinidae larval and Chrysomelidae adult and larval fragments in the total arthropod fragment composition of chick fecal samples collected from gray partridge roost sites (r = 0.78, 7 df, $P <$ 0.05; Fig. 2A). There was also a positive relationship between percentage chick survival per brood (to 21 days old) and the collective total proportion (percentage) of Tenthredinidae larvae and Heteropteran and Staphylinidae larval fragments in the total arthropod fragment composition of chick fecal samples from pheasants (r = 0.74, 20 df, $P < 0.002$; Fig. 2B).

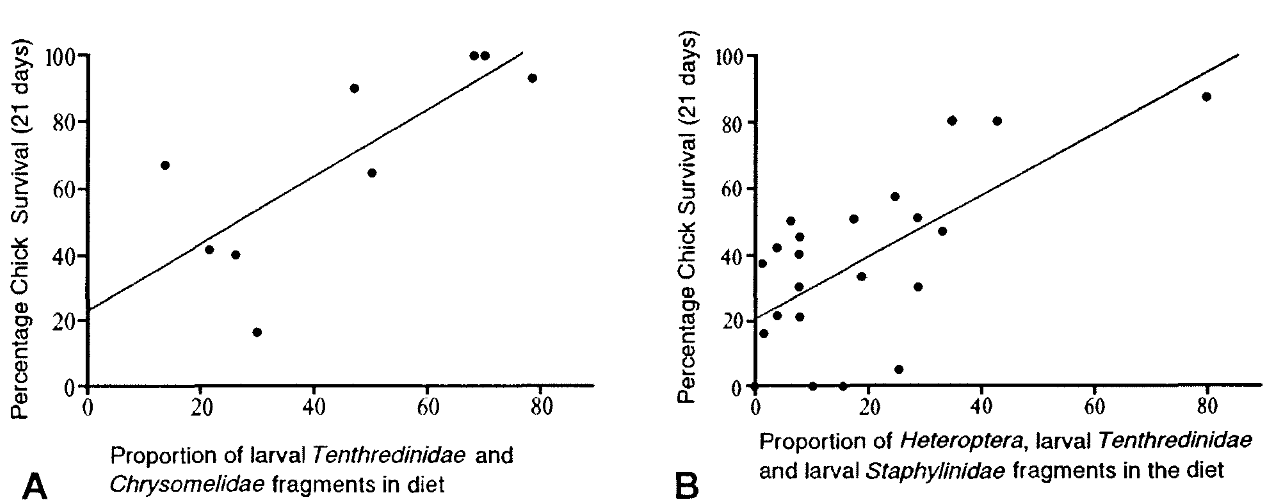

Fig. 2. The effect of an increasing proportion of preferred arthropod food items in the diet of (A) gray partridges and (B) ring-necked pheasants on chick survival to 21 days old (data derived from radio-tagged females and analysis of chick feces collected from roost sites).

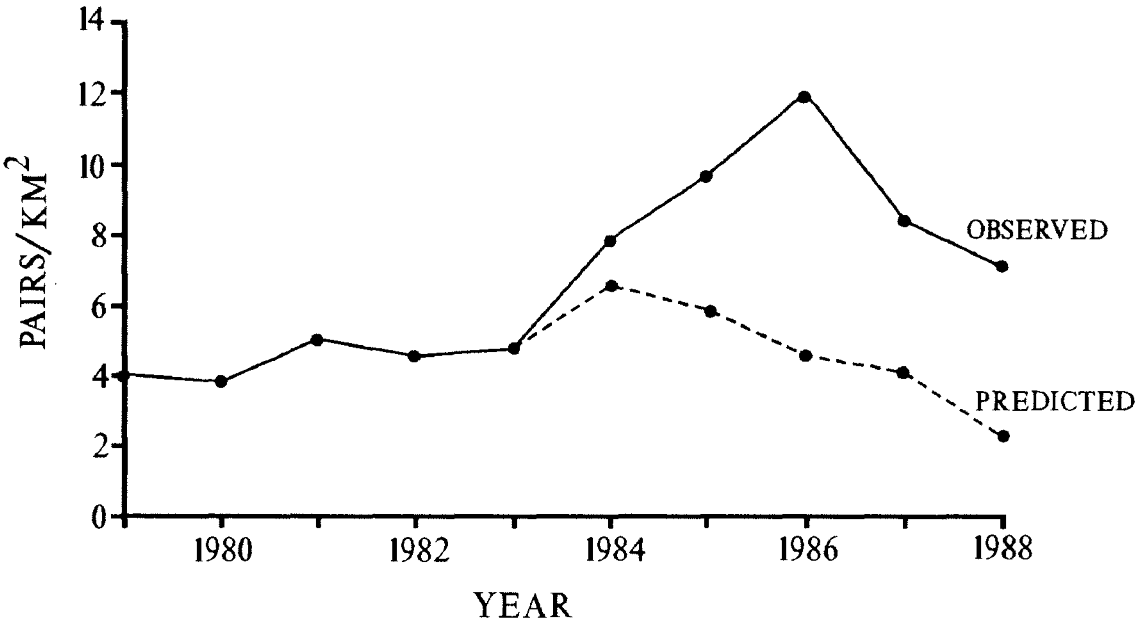

Fig. 3. Changes in gray partridge spring breeding density before (1979-83) and after (1984-88) introduction of selective pesticide application to cereal field headlands on the principal study farm in 1983, together with a predicted estimate of breeding densities without headland pesticide manipulation (1984-88).

Spring Pair Counts.—Longer term consequences of Conservation Headlands on the principal study farm were to increase the breeding stock of gray partridges (Fig. 3). Experiments began on the farm in 1983 when spring breeding density had reached 4 and 5 pairs per km^2. Game records on this estate have been kept since the last century and the immediate post-war density of gray partridges was recorded at about 18 pairs per km^2. In the intervening years densities had fallen on the farm to the low levels observed before our experiments began. This decline followed the national rate of decrease in abundance reported earlier and elsewhere (Potts 1986). Spring density rose from about 4 pairs in 1983 to 8 in 1984 and continued until 1986 to peak at 11.7 pairs per km^2. Data collected over the same period showed that such increases were not observed on other estates in the vicinity (Sotherton et al. 1989).

However, after 1986, densities of spring pairs fell back to about 7 pairs per km^2. It is possible that increasing partridge densities contributed to increased rates of predation which are known to operate in a density-dependent manner (Potts 1986), and this slight decline in abundance coincided with seasons in which cold wet spring/summer weather led to generally low levels of chick survival.

Computer simulations of spring breeding density in the absence of Conservation Headlands, based on rates of chick survival in these poor years and initial increases in predator pressure were calculated. These revealed that the fall in spring density could have been far greater without the cushioning effects of these management techniques to alleviate pesticide pressures on the food chain (G. R. Potts, unpubl. data; Fig. 3).

CONCLUSIONS

The production of a huntable surplus of wild game birds in the agricultural landscapes of the UK depends on successful management of 3 essential aspects of their biology. This paper has summarized research efforts which have addressed 1 of these essential features: the production of adequate chick-food insects to increase chick survival. The Conservation Headlands technique has been a successful solution to the problem of pesticides and their negative impacts on nontarget organisms in game-bird chick-food chains. However, Conservation Headlands alone cannot be considered all that is necessary to increase population densities. The other 2 essential features must also be considered. These are the provision of adequate amounts of quality nesting cover and, by legal control of predators, protection of eggs and incubating females during the nesting season. Only by provision of all of these elements will sustainable wild game-bird production be achieved.

In Europe, problems of production of farm commodities have recently emerged, whereas they have been a part of land management in North America for over 40 years. Before considering management of diverted land for wild game, requirements for nesting cover and refuges from predation and brood rearing must be known. In the UK brood-rearing areas have 3 essential features. They need to be rich in insects within a canopy of vegetation, and that vegetation must not be too dense or moisture-retentive to be either impenetrable for small chicks or a hostile environment in wet weather. Small grain cereal fields with low agrochemical inputs provide these structural and biological features, making them ideal brood-rearing areas. If set-aside land or land incorporated into longer term conservation programs is to be managed for game birds, the value of land sown with native grasses or exotic crops (alfalfa, sainfoin, etc.) has to be assessed. That former arable land sown with grasses or left fallow to regenerate its own flora will provide nesting cover could probably be accepted. That such areas will provide good brood cover is much less certain and requires the urgent attention of our research efforts. Preliminary estimates have been made of rates of chick survival of broods reared on set-aside land and compared with rates from conventional cereal crops and cereal crops surrounded by Conservation Headlands. Results obtained in 1991 (an exceptionally poor year for gray partridge chick survival in the UK), showed 7.9% survival on set-aside land with an average mean brood size of 2.0 ± 0.6 chicks. This compared with a rate of survival between 18 and 21% in cereal crops where mean brood sizes averaged 4.9 chicks.

We encourage farmers to grow low input crops of small grain cereals containing abundant food resources for chicks. In the UK, almost all cereal fields receive annual applications of herbicides, insecticides, and fungicides (Rands et al. 1988). For example in 1990, in England and Wales 74% of all wheat crops received an application of an insecticide, 97% an application of a fungicide, and 98% an herbicide. The average wheat crop was sprayed 4.4 times using an average of 8.0 products, and 9.8 active ingredients (Davis et al. 1991). In North America, pesticide inputs are far lower as are corresponding yields, and as such the adverse side-effects may be less apparent. To rectify the problem in Europe, we recommend adopting more extensive methods of production such as lower inputs of agrochemicals (pesticides and inorganic fertilizers), the return to spring drilling, and the adoption of greater use of temporary grassland in the arable rotation (3 years) to avoid cereal monocultures. In North America, if pesticides are shown to be a problem, this would mean changing regulations concerning the compliance monitoring of annual set-aside programs to better fit in sympathetically with game-bird chick phenology; for example the use of oats as a cover crop which must be plowed in before an arbitrary date. Such a solution demonstrably helps game, reduces surplus, and also helps answer the socioeconomic consequences of not keeping farmers farming.

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