The Potential Value of the Field Scale Evaluation in Assessing the Impact of GMHT Crops on Birds and Mammals

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EXECUTIVE SUMMARY

1. The effects of genetically modified herbicide-tolerant (GMHT) crops on farmland biodiversity in Britain are being assessed by comparing the abundance of various taxa between conventional and GMHT halves of experimental fields in a large-scale experiment termed the Farm-Scale Evaluation (FSE).

2. Surveys of birds and mammals were carried out in spring and summer 2000 and in winter 2000/01 (birds only) in order to assess the feasibility of monitoring birds and mammals as part of the FSE. Specifically, this project aimed to assess the power of the FSE experimental design to detect differences in the utilisation of conventional and GMHT crop. This was achieved through a power analysis of various measures of bird and mammal occurrence for selected species, including measures of bird foraging activity in the crop.

3. For the spring and summer survey, a total of 24 sugar beet sites, 11 maize sites and 10 rape sites were surveyed, but many species were absent from several sites. Three different survey approaches were used: territory mapping of all birds in the experimental and surrounding field boundaries; point counts of birds in fields (to record foraging events); and foraging observations of aerial feeders. Mammals were recorded when located during any bird surveys. Observers had no prior knowledge of how each half of a field had been treated.

4. The power analysis was based on Poisson and binomial models incorporating site and treatment effects. Three different comparisons were made: GMHT vs conventional crop over the whole survey period, GMHT crop before herbicide application vs conventional crop in the same time period (i.e. early in the season) and GMHT crop after herbicide application vs conventional crop in the same time period (i.e. late in the season).

5. Ten bird species were selected for analysis based on their abundance and detectability given the survey methods used and also to represent a range of dietary preferences. The species were Red-Legged Partridge *Alectoris rufa*, Skylark *Alauda arvensis*, Wren *Troglodytes troglodytes*, Dunnock *Prunella modularis*, Whitethroat *Sylvia communis*, Robin *Erithacus rubecula*, Blackbird *Turdus merula*, Song Thrush *T. philomelos*, Chaffinch *Fringella coelebs* and Yellowhammer *Emberiza citrinella*. For aerial feeders four species were considered: Swallow *Hirundo rustica*, Sand Martin *Riparia riparia*, House Martin *Delichon urbica* and Swift *Apus apus*, but only Swallow occurred in sufficient numbers for analysis.

6. Most analyses had low power to detect significant differences in the data collected. The most powerful analyses involved a comparison of GMHT treated (i.e. sprayed) crop with conventionally treated crop later in the breeding season. Point counts collecting foraging data were most likely to yield analyses of high power in this data set.

7. Simulated data for additional sites showed surveys of Red-Legged Partridge, Swallow, Dunnock, Wren, Whitethroat, Blackbird, Chaffinch and Yellowhammer were predicted to achieve 90% power given the combined sample sizes for 2000 and those to be part of the FSE in 2001. Results for maize (an expected total of 39 sites)

were of relatively high power in comparison with results from sugar beet (50 sites). Oilseed rape (37 sites) had the analyses of lowest power with no species predicted to achieve adequate power with additional sites.

8. In the case of mammals, only Hare *Lepus europeaus* and Rabbit *Oryctolagus cuniculus* were recorded in sufficient numbers for analysis and these were of lower power relative to the bird analyses. Rabbit presence on sugar beet crops was the most powerful analyses and 90% power was predicted with a total of <24 sites. Caution should be exercised when interpreting these data as the methods used were not designed specifically for surveying mammals.

9. A general power model based on all bird species combined was carried out to determine the differences in bird abundance between GMHT and conventional crop required to achieve 90% power, given typical abundances and average differences detected during this study. This predicted that to achieve a statistical comparison with 90% power, a difference of approximately 125% in numbers (i.e. more than double) between treatments would be required for sample sizes of 40-60 sites (the range of sample sizes expected with additional sites in future years) for Poisson models. For binomial models, the odds ratio would need to be approximately 9 times greater on one treatment for 40-60 sites to achieve 90% power.

10. Summarising findings from the spring and summer fieldwork, the power analyses presented here indicate that 8 species have the potential power to detect significant differences in bird abundance or occurrence between treatments with the additional sites proposed for 2001. Point counts recording foraging individuals on maize crops in the later half of the breeding season, (i.e. after herbicides application to GMHT crops) are likely to yield the most powerful analyses. Detection of significant differences in mammal abundance was less likely.

11. The introduction of GMHT crops has the potential to markedly reduce the abundance of weed plants and hence the availability of weed seeds in post-harvest crops relative to non-GMHT crops. A power analysis was carried out on bird survey data collected from 69 experimental sites, divided equally into GMHT and conventional halves, in winter 2000/01. This sample of fields partially overlapped the spring/summer sample.

12. Bird surveys were carried out between October and February and consisted of whole-area searches of birds using each field. A total of 23 former sugar beet fields, 11 former maize fields and 12 former spring oilseed rape fields were surveyed. Of these 25 were left as bare plough over the winter and 17 were left as stubble. Remaining sites were either planted with other crops or were dropped from the analysis because winter management was not exactly the same on either half of the field. Additionally, 23 winter oilseed rape fields were surveyed.

13. Poisson and binomial models were fitted to the data which incorporated site, date and treatment effects (GMHT or conventional). Models were derived for any species occurring on four or more sites. Models were run on separate crop types, firstly according to the former crop type and secondly according the current crop type. Parameter estimates for the treatment effect derived from the above models were used as the basis for a power analysis.

14.   Several species were predicted to produce power of greater than 90% with less than 100 sites. Stubbles and former maize and sugar beet sites had the greatest number of species predicted to achieve this level of power (5, 4 and 4 species respectively). Crop types were not mutually exclusive, however, as the majority of maize and spring rape sites were left as stubble and the majority of sugar beet sites were left as bare plough.

15.   Five species were predicted to achieve 90% power with the sample sizes expected to be part of the FSE in winter 2001/02. These were Pheasant, Skylark, Meadow Pipit, Blackbird and Linnet. Skylark was predicted to achieve 90% power on the most crop types.

16.   We suggest that a winter survey of stubbles from former maize and spring rape crops is likely to yield analyses of sufficient power for Skylark, Blackbird (Poisson models) and Linnet (binomial models). Skylark was the best candidate for further research. It is unlikely that surveying other crops would provide a cost-effective means of assessing the effects of GMHT crop management on the abundance of birds in winter. The suitability of the FSE for assessing impacts of GMHT management on birds in winter would be greatly enhanced if the experimental design was such that all fields were left as stubbles and both GMHT and conventional halves were treated in the same way.

17.   Pilot work was also carried to assess the feasibility of measuring intake rates of foraging birds on the FSE sites through direct observation. This work suggests that, although collecting adequate data to estimate intake rates on GMHT and conventional field halves would require extensive fieldwork, it may be possible for a small number of species including skylark and yellowhammer using crop stubbles.

18.   There is an important caveat relating to these results. Crucially the findings are dependent on acceptance of the assumption that derived parameter estimates are likely to remain similar when further sites are surveyed (e.g. that the mean difference from 5 sites would be the same as the mean difference from 50 sites). Caution is therefore needed when interpreting these power analyses due to the small sample sizes involved.

19.   Due to the above caveat, we suggest that the analysis presented in this paper should be used as a baseline to direct future studies on breeding and wintering birds rather than be used as a definitive statement of the power of the current GMHT trials to detect differences in bird abundance. Specifically, these analyses have indicated that surveys of foraging birds (rather than overall measures of bird abundance), especially in maize crops (summer) and maize and spring oilseed rape stubbles (winter), may provide the greatest potential to assess the effects of GMHT crops on birds.

CHAPTER 1   THE EFFECTS OF GMHT CROPS ON SUMMER BIRD AND MAMMAL OCCURRENCE – A POWER ANALYSIS

1.   SUMMARY

1.   The effects of genetically modified herbicide-tolerant (GMHT) crops on farmland biodiversity are being assessed by comparing the abundance of various taxa between conventional and GMHT halves of experimental fields in a large-scale experiment termed the Farm-Scale Evaluation (FSE).

2.   A bird and mammal survey was carried out in spring and summer 2000 in order to assess the feasibility of monitoring birds and mammals as part of the FSE. Specifically, this project was designed to assess the power of the FSE experimental design to detect differences in the utilisation of conventional and GMHT crop. This was achieved through a power analysis of various measures of bird and mammal occurrence for selected species, including measures of foraging activity in the crop.

3.   A total of 24 sugar beet sites, 11 maize sites and 10 rape sites were surveyed, but many species were absent from several sites. Three different survey approaches were used: territory mapping of all birds in the experimental and surrounding field boundaries; point counts of birds in fields (to record foraging events); and foraging observations of aerial feeders. Mammals were recorded when located during any bird surveys. Observers had no prior knowledge of how each half of a field had been treated.

4.   The power analysis was based on Poisson and binomial models incorporating site and treatment effects. Three different comparisons were made: GMHT vs conventional crop over the whole survey period, GMHT crop before herbicide application vs conventional crop in the same time period (i.e. early in the season) and GMHT crop after herbicide application vs conventional crop in the same time period (i.e. late in the season).

5.   Ten bird species were selected for analysis based on their abundance and detectability given the survey methods used and also to represent a range of dietary preferences. The species were Red-Legged Partridge *Alectoris rufa*, Skylark *Alauda arvensis*, Wren *Troglodytes troglodytes*, Dunnock *Prunella modularis*, Whitethroat *Sylvia communis*, Robin *Erithacus rubecula*, Blackbird *Turdus merula*, Song Thrush *T. philomelos*, Chaffinch *Fringella coelebs* and Yellowhammer *Emberiza citrinella*. For aerial feeders four species were considered: Swallow *Hirundo rustica*, Sand Martin *Riparia riparia*, House Martin *Delichon urbica* and Swift *Apus apus*, but only Swallow occurred in sufficient numbers for analysis.

6.   Most analyses had low power to detect significant differences in the data collected. The most powerful analyses involved a comparison of GMHT treated (i.e. sprayed) crop with conventionally treated crop later in the breeding season. Point counts collecting foraging data were most likely to yield analyses of high power in this data set.

7. Simulated data for additional sites showed surveys of Red-Legged Partridge, Swallow, Dunnock, Wren, Whitethroat, Blackbird, Chaffinch and Yellowhammer were predicted to achieve 90% power given the combined sample sizes for 2000 and those to be part of the FSE in 2001. Results for maize (an expected total of 39 sites) were of relatively high power in comparison with results from sugar beet (50 sites). Oilseed rape (37 sites) had the analyses of lowest power with no species predicted to achieve adequate power with additional sites.

8. In the case of mammals, only Hare *Lepus europeaus* and Rabbit *Oryctolagus cuniculus* were recorded in sufficient numbers for analysis and these were of lower power relative to the bird analyses. Rabbit presence on sugar beet crops was the most powerful analyses and 90% power was predicted with a total of <24 sites. Caution should be exercised when interpreting these data as the methods used were not designed specifically for surveying mammals.

9. A general power model based on all bird species combined was carried out to determine the differences in bird abundance between GMHT and conventional crop required to achieve 90% power, given typical abundances and average differences detected during this study. This predicted that to achieve a statistical comparison with 90% power, a difference of approximately 125% in numbers (i.e. more than double) between treatments would be required for sample sizes of 40-60 sites (the range of sample sizes expected with additional sites in future years) for Poisson models. For binomial models, the odds ratio would need to be approximately 9 times greater on one treatment for 40-60 sites to achieve 90% power.

10. In summary, the power analyses presented here indicate that 8 species have the potential power to detect significant differences in bird abundance or occurrence between treatments with the additional sites proposed for 2001. Point counts recording foraging individuals on maize crops in the later half of the breeding season, (i.e. after herbicides application to GMHT crops) are likely to yield the most powerful analyses. Detection of significant differences in mammal abundance was less likely.

11. There is an important caveat relating to these results. Crucially the findings are dependent on acceptance of the assumption that derived parameter estimates are likely to remain similar when further sites are surveyed (e.g. would the mean difference from 5 sites be the same as the mean difference from 50 sites). Caution is therefore needed when interpreting these power analyses due to the small sample sizes involved.

12. Due to the above caveat, we suggest that the analysis presented in this paper should be used as a baseline to direct future studies rather than be used as a definitive statement of the power of the current GMHT trials to detect differences in bird abundance.

2.   INTRODUCTION

Recent advances in recombinant DNA technology have lead to the development of genetically modified organisms. In agriculture, genetically modified herbicide-tolerant (GMHT) crops are already commercially grown in the USA and China. These differ from conventionally managed crops in that broad spectrum herbicides (e.g. Glyphosate) can be applied, thus killing all plants save the GMHT crops. This is attractive to farmers because it is both more effective and less costly than conventional management, but also because far fewer applications are needed (e.g. the need for pre-emergence spraying is removed). However, concerns over potential environmental costs related to the introduction of GMHT crops have been raised. These include the introgression of transgenes into weedy relatives of crops and the loss of farmland biodiversity due to the complete removal of weeds from crops (Hails 2000). This study is concerned with the latter factor.

Farmland biodiversity has shown general declines over the past three decades (Krebs et al. 1999). Declines in birds at least are closely linked to agricultural intensification (Chamberlain et al. 2000). Removal of weed plants could have important implications for granivorous birds (Watkinson et al. 2000) and further intensification caused by the introduction of GMHT crops could potentially have severe impacts on the bird community. However, there may be potential environmental benefits of the introduction of GMHT crops in that fewer sprayings may encourage minimum tillage systems and spring sowing. Furthermore, increased productivity may mean that there is the potential for a greater proportion of land to be put into set-aside or agri-environmental schemes (Hails 2000). Later spraying may also mean that weeds are tolerated in the crop for longer periods than under conventional management.

The potential effects of GMHT crops on farmland biodiversity are currently being investigated by the Department of Environment, Transport and Regions under the Farm-Scale Evaluations (FSE) project. This considers the effects of GMHT crops compared to conventionally managed crops on a range of taxa in a large-scale field experiment. The findings of the FSE will be used to make recommendations on the likely impacts of GM crops to farmland biodiversity. These findings will influence government policy on the commercial introduction of GMHT crops. Experimental rigour is an extremely important issue and before conclusions are drawn from the FSE about environmental impacts, the feasibility of the experimental approach and the reliability of subsequent results needs to be assessed. In this paper, we present results from a pilot study that considered the differences in bird and mammal occurrence between GMHT and conventional crops on FSE sites. A power analysis is carried out on the data in order to assess the feasibility and value of incorporating bird and mammal surveys into the main FSE programme.

3.   AIMS

The aims of this study were (i) to determine the number of experimental sites likely to be required in the FSE if statistically significant differences in bird and mammal occurrence (expressed using a variety of measures) are to be detected between GMHT conventional crops; and, (ii) to identify the crop types, species and methods which are likely to provide the most powerful tests of the influence of the use of GMHT versus conventional crops on bird and mammal occurrence. As the goal of this analysis is to determine adequate sample sizes required rather than actually compare treatment types, different treatment types will not be explicitly identified in the text and no conclusions will be drawn on likely impacts of GMHT crops on bird or mammal occurrence from this study.

4.   METHODS

4.1   Sites

Sites were distributed throughout England and Scotland (Fig. 1). Each site consisted of one or more experimental fields (no single site had more than one of the same crop type) that were divided equally into GMHT and conventional treatments by a bare strip. Each treatment followed recommended spraying regimes for that particular crop type. A full description of the experimental design is given in Perry et al. (in press). Three different crop types were used: sugar beet, maize and spring rape with respective sample sizes of 24, 11 and 10 (two additional sites rape sites and one maize site were covered but were vandalised during the course of the survey period and so were not included in the analysis).

4.2   Bird Survey

There were three different surveys undertaken: a territory mapping survey of all birds in the experimental field and surrounding field boundaries; point counts of birds in fields; and foraging observations of aerial feeders. Observers had no prior knowledge of how each half of a field had been treated, so the results should not be affected by any preconceptions they may have had.

(i)   Territory mapping survey: Each site was visited five times between April and August. On each visit the location of all birds seen in the experimental field, the surrounding field boundaries and in the immediately adjacent fields and field boundaries were recorded onto maps following standard recording protocols used in the BTO's Common Birds Census (Marchant et al. 1990). This included birds involved in any activity apart from flying over the site, unless flight was likely to be associated with the field itself (song flights or hunting flights). Particular care was taken in recording bird locations in relation to the GM/conventional divide in the experimental field. Individual registrations that made up each territory were assigned to given habitat types (hedgerow unit, either half of experimental field).

(ii)   Point counts: After the territory mapping survey had been carried out, the observers carried out a number of point counts, recording birds using the experimental field. This differs from the above not only in the actual methodology, but also as this only recorded birds that actually landed in either half of the field (singing birds and birds overhead were not included). A number of evenly spaced points were identified along the field perimeter (the same locations were used on each visit) and at each of these points the observer recorded all movements of birds to, from and within the experimental field using standard activity codes and site maps. The point count duration was 5 minutes and observers carried out 10 point counts per visit. These data were expressed in two ways. Firstly, the number of foraging events was recorded, where 1 event = a bird entering or leaving the crop. It was assumed that such birds were foraging in the crop, although it was rarely possible to observe birds feeding. Analysing the data in this way assumes that the overall use of a crop by birds is a good measure of the food available in that crop, but this takes no account of the independence of data points, i.e. an individual bird seen entering or leaving a crop ten times during a point count would be recorded as ten foraging events. The second data set did not take into account the use being made of the crop, but just considered the

number of individual birds estimated to be foraging, whether they were seen entering/leaving the crop once or several times.

(iii)   Aerial feeders: A number of experimental sites were surveyed to determine their use by foraging Hirundines and swifts in August. A viewing point was located over the crop where a 5m wide observation transect could be identified (e.g. by using landmarks), preferably towards the centre of the treatment (i.e. GMHT or conventional) and parallel to the crop divide (so there was no chance of counting Hirundines over the other treatment). Transects were selected to be of equal length. After the normal survey had been undertaken, the observer stood at this point and counted any Hirundines actively foraging that crossed the transect in a 10 minute period, up to a height of ten metres. This was done for both treatments separately. The maximum number of birds that were within the transect at any one time during the 10 minute period was also recorded.

Data for ten selected species were analysed for data sets (i) and (ii). Selection was based on abundance, detectability given the survey methods and also to represent a range of dietary preferences. The species were Red-Legged Partridge *Alectoris rufa*, Skylark *Alauda arvensis*, Wren *Troglodytes troglodytes*, Dunnock *Prunella modularis*, Whitethroat *Sylvia communis*, Robin *Erithacus rubecula*, Blackbird *Turdus merula*, Song Thrush *T. philomelos*, Chaffinch *Fringella coelebs* and Yellowhammer *Emberiza citrinella*. For aerial feeders four species were considered: Swallow *Hirundo rustica*, Sand Martin *Riparia riparia*, House Martin *Delichon urbica* and Swift *Apus apus*.

4.3   Mammal Survey

Throughout the duration of all bird surveys, the identity, location and number of any mammals seen within the experimental field was recorded on site maps.

5. ANALYSIS

5.1 Modelling Abundance and Presence/Absence

For birds, a number of different data sets were analysed, but they could be divided into two main groups: bird counts and bird presence. Bird counts were analysed with Poisson regression. This included most of the data collected: number of individual bird registrations per visit from territory mapping, foraging events per visit from point counts (i.e. summed over all ten point counts), number of foraging individuals from point counts, the number of foraging passes made by aerial feeders and the number of individuals of aerial feeders present at any one time in a transect. Furthermore, bird registrations were divided into two data sets. First, the whole data set which incorporated field and boundary registrations; and second, only registrations actually recorded in the crop itself were analysed.

The three crop types were analysed separately using the GENMOD procedure in SAS (SAS Institute, 1996). The effect of field treatment on bird abundance was analysed using the basic generalized linear model:

$$abundance = \exp[\text{intercept+site+treatment}]$$

which used a log link function and assumed a Poisson error distribution. Birds abundance was summed over all visits and the number of visits (log-transformed) was used as an offset in the model. The site effect was a dummy variable that described variation caused by the location of the site (e.g. altitude, geographic location, distance from coast etc.) that may have had a significant effect on bird abundance. Including this variable maintained the paired structure of the fields in the analysis. Treatment was GMHT or conventional. For all analyses, the scaled deviance was used to correct for over-dispersion.

Typically, the GMHT crop was sprayed at a different time to the conventional crop. Therefore, each treatment half was recorded as sprayed or unsprayed. In addition to considering a comparison of GMHT vs conventional over the whole season, models were also developed which took into account the timing of herbicide treatment, i.e. GMHT unsprayed versus conventional (referred to as the EARLY data set), and GMHT sprayed versus conventional (LATE data set). These data sets were mutually exclusive. Birds recorded in field boundaries were assigned to the adjacent treatment.

In addition to modelling the abundance of species, the probability of a species being present was analysed by reducing the data to a binomial, expressed as the number of visits on which a species was present out of the total number of visits. This used a similar model to the above, but a binomial error structure was assumed and a logit link function was used with the same input variables. No offset term was used in this model. The number of mammals recorded per visit and the presence of mammals recorded per visit were analysed using Poisson and binomial models respectively as described for the bird registrations data, but this considered only mammals recorded in the experimental field and not in the adjacent boundary. A summary of all different data sets analysed is given in Table 1. Each variable was analysed over the whole season (WHOLE), in the early season before application of herbicide (EARLY) and after application of herbicide (LATE) with the exception of aerial foragers which were only surveyed in the LATE data set.

The number of sites in the models varied from species to species because all species did not occur at all sites. Sites with zero counts on both treatments for a given species were not analysed. This has important implications when determining the power of the analysis (see below).

5.2   Power Analysis

The models generated from the above procedures were used to provide realistic parameter estimates as the basis for the power analyses. Estimated bird or mammal abundance was determined from the parameter estimates derived from each model. This value was then used as a mean for a randomly generated Poisson or binomial distribution as appropriate, with the same sample size as the original data set. The purpose of this quasi-random selection was to simulate a further identical survey, making the important assumption that the effects of the model variables in a large number of simulations would be the same. When a quasi-random data set had been generated, it was analysed using the same model. This procedure was repeated 1000 times (thus simulating 1000 identical surveys). The proportion of these simulations yielding a significant effect of treatment in addition to the effects of site and date (Type 1 analysis; SAS 1996) with the same relative ranking of treatment effects as derived from the original analysis was taken as a measure of statistical power. Power was defined as one minus the probability of accepting, falsely, a null hypothesis that two compared treatments are equal. That is, the power is the probability of the treatment which has the highest true effect being correctly identified as such in the analyses (i.e. analyses assume that the parameter estimates in the model were representative of 'real' effects). Here, as is conventional, power is expressed as a percentage.

The next step was to determine the power when the number of sites was increased. A dummy data set of additional sites was created for each simulation. Parameter estimates for the sites were obtained by generating quasi-random numbers from a normal distribution with a mean equal to the mean of the actual parameter estimates from the original model for each species. There were three such dummy data sets containing 10, 20 and 40 sites. For each of these scenarios, a power analysis with 1000 simulations was carried out in the same way as described above. As sites with zero counts for a given species were omitted from the original analysis, the simulations ensured that no randomly-generated data sets contained sites with zero counts for particular species. The sample size for each analysis was the original sample size plus 10, 20 and 40 extra sites. The effect of increasing sample size on the power of the analysis could then be considered by plotting power against sample size. However, the original data set omitted any sites without birds, and a proportion of any extra sites is likely to have zero counts for particular species. Because all the extra sites had non-zero counts, the sample size for each species was adjusted using the proportion of actual zero counts. This is best illustrated by example. Suppose that Wren occurred on only half of all sites for a given crop. The model and parameter estimates are therefore based on only half of the total number of sites. If an extra 10 sites with Wrens were added to the original data, it was assumed that this represented half the actual sample size, i.e. it was assumed that to get data from 10 sites with Wren present, 20 sites would have to be surveyed. In estimating increases in power with respect to the number of sites, this adjusted sample size is used, so for an extra 10, 20 and 40 sites with birds, the power in this example would be plotted against an extra 20, 40 and 80 sites. Power was therefore determined not in relation to the sample size in the analysis, but to the effort required to achieve that sample size. Particularly rare species will therefore have very large adjusted sample sizes for additional sites in this analysis.

The sample size required to achieve a given power can be determined simply from figures produced by the above analysis (Fig. 2). A level of 90% power is used throughout this paper. So, in the example in Fig. 2, 56 sites would be needed to be 90% certain of detecting a significant difference, if the assumptions about the representativeness of the data are valid.

6.   RESULTS

6.1   Model Results

With the exception of the data for aerial feeders, an attempt was made to derive a model for each of the ten species in each data set. However, in a number of cases, no valid models were produced (parameter estimates were not produced or the models had extremely large errors, implying numerical problems). This was generally due to small sample sizes, and there were also some species which were not recorded in a particular data set. A summary of all model results for species occurring on at least four sites is given in Appendix 1. The parameter estimates derived from these models are expressed as the number of birds (Poisson model) or probability of occurrence (binomial model) relative to one of the treatments (selected at random for each model). This is in order to show the magnitude of the differences found between treatments and the precision with which it is known. These tables do not show which treatment had higher or lower parameter estimates, only whether a significant difference was detected. The dispersion is the deviance divided by the degrees of freedom which gives a measure of model fit which is less good the further away the value is from 1. Use of the DSCALE option (SAS Institute, 1996) adjusts standard errors to correct for overdispersion.

Sample sizes and the number of models producing parameter estimates were relatively low in the EARLY data set. For aerial feeders, only Swallow produced sample sizes large enough for analysis. Only two species of mammal were recorded in sufficient numbers for analysis, Hare *Lepus europeaus* and Rabbit *Oryctolagus cuniculus* (Brown Rat *Rattus norvegicus* and Red Fox *Vulpes vulpes* were the only other mammals recorded, with one and two observations respectively). Model details for mammals are given in Appendix 2.

6.2   Power Analysis

The power of the analyses given in Appendix 1 and the number of sites required to achieve 90% power (determined using the method described by Fig. 2) are shown in Table 2 for those species where fewer than 100 sites would be required in the WHOLE data set. Considering the large number of analyses run (Appendix 1), there were relatively few cases where 90% power was achieved – 12 individual analyses involving 6 species (Table 2). In most cases, this was due to very small differences in bird occurrence between treatments, although in some cases there were extreme site effects which clearly influenced the power analysis. As a proportion of all analyses run, foraging events was the variable that was most likely to produce models of relatively high power. Data from maize crops were most likely to yield high power analyses.

The power and the number of sites required to achieve 90% power for data analysed according to herbicide treatment is shown in Table 3. In the EARLY data set, there were 11 individual analyses involving 5 species where 90% power was achieved (Table 3a). Again maize was the crop which had the most number of models where fewer than 100 sites was estimated to achieve 90% power. In the LATE data set, there were many more models estimated to achieve 90% - 35 individual analyses involving 10 species (Table 3b). In Tables 2 and 3, there are a number of cases where the same species in the same crop appears a number of times (e.g. Blackbird in maize crops in Table 3a and Yellowhammer on maize crops in Table 3b). It should be stressed that these variables are not independent.

The information provided in Tables 2 and 3 can be used to identify those species and those measures of species occurrence (e.g. abundance, presence/absence, foraging events) that would provide the most powerful analyses for given sample sizes. For example, Table 4 shows those species that are predicted to achieve 90% power with total sample sizes based on the number of sites in 2000 which have been used in these analyses (24 sugar beet, 11 maize, 10 rape) plus the number of sites planned for 2001 (a further 26 beet, 28 maize and 27 rape sites). For a comparison of GMHT versus conventional over the whole season, five species were predicted to achieve 90% power to detect significant differences with these additional sites: Red-Legged Partridge, Dunnock, Whitethroat, Chaffinch and Yellowhammer. For the EARLY data set, Blackbird was the only species where 90% power was predicted. For the late data set, six species were predicted to achieve 90% power: Red-Legged Partridge, Swallow, Wren, Dunnock, Blackbird and Yellowhammer. This data set had the largest number of individual analyses achieving 90% power. Variables that were measuring foraging rate or foraging individuals had the highest power and those measuring probability of presence the lowest. There were no species predicted to achieve 90% power with additional rape sites. Maize had the highest proportion of analyses predicted to achieve 90% power with additional sites, with 17 individual models and 7 species (equivalent figures for sugar beet were 5 and 2 respectively).

The results of the power analysis for mammals is shown in Table 5. Statistical power of 90% was predicted with under 100 sites for Rabbit presence on sugar beet in the WHOLE data set, Hare abundance on maize in the EARLY data set and for Rabbit abundance on sugar beet in the LATE data set. Additional sites in 2001 would increase the sample size enough to achieve 90% power only for Rabbit presence on sugar beet.

6.3   General Relationships Between Sample Size, Parameter Estimates and Power

The above analyses give an indication of which species are likely to provide the most powerful analyses under a range of different measures and in different crops. If we pool results from all species and crop-specific analyses, we can use the randomly generated data to make general conclusions about sample sizes and average differences in bird occurrence required to achieve a given level of power. The power of an analysis to detect significant differences between treatments will be determined by the sample size of the data and the level of difference between treatments. The data simulation procedure used to generate the results in Table 2 and 3 provide a wide range of values for both of these variables. By plotting the power of an analysis against the parameter estimates (Appendix 1), we can then determine the magnitude of the difference between treatments required to achieve a given level of power for a given sample size. For the calculations of power and sample size required to achieve given levels of power in Table 2 and 3, adjusted sample sizes were used based on the proportion of sites where a given species occurred. This adjusted sample size rather than the actual sample size will be used in the following analysis.

Fig. 3 shows the power (i.e. proportion of significant treatment effects out of 1000 simulated models) plotted against the relative abundance of birds where each point represents the power from individual species/crop/data type (e.g. number of registrations, foraging events) models in Appendix 1 with varying sample size. The measure of relative abundance was calculated by transforming treatment parameter estimates derived from Poisson regression and setting the lower parameter estimate to 1. Therefore, a value of 1.5 indicates that 50% more birds (or foraging events or other count variable) were found on one of the treatments. This figure uses all data (WHOLE, EARLY and LATE data sets combined). Three separate, arbitrarily chosen

scenarios are given based on the adjusted sample size, e.g. a species occurring on 12 out of the original 24 sugar beet sites has ten extra sites added and the power of the analysis is estimated accordingly, but this power is plotted against the adjusted sample size of 44 (24 original sites + 20 further sites required to cover 10 sites with birds). This point would therefore be in the 40-60 sites category.

The curves added to aid visual examination of the data in Fig. 3 are logistic curves (to ensure predicted power was constrained to remain between 0 and 100%). For a survey with between 40 and 60 sites, 90% power would be achieved with a relative difference in abundance between treatments of 2.25. For the higher sample sizes, the difference in relative abundance needed to achieve 90% power was similar at 2.14 for 61-80 sites and 1.89 for 81-100 sites. The plots show a certain amount of scatter (Fig. 3). This occurs for three reasons. First, the power is really determined by the original sample size in the model (i.e. the number of sites with birds) which will vary (sometimes considerably) between species. Second, in some simulations, no valid statistics were produced (e.g. a given species may have produced 800, rather than 1000 simulated model results), but the power was still based on 1000 simulations. In the latter example, if 200 simulations produced significant results, the power would be expressed as 20%, but it could be argued that it should be 25%. In these cases, we have opted for lower estimate of power as this is a reflection of the quality of the data. Such cases only arose when the data were particularly sparse or sample sizes were very small and in practice most Poisson analyses had at least 900 simulations that produced results so this is a minor problem. Third, and most important, the absolute difference as well as the relative difference will have an influence on the power. For example, fields averaging 10 birds on one treatment and 20 birds on another is likely to yield greater power than fields with 2 and 4 birds respectively, yet they would both have a relative abundance of 2 in Fig. 3. However, in these data, the majority of species were in a similar range of abundance. For example, only 25 out of a total of 121 Poisson models from all data sets (see Appendix 1) produced estimated counts of over 10 and only 2 models had estimated count greater than 20. Therefore, Fig. 3 should be generally applicable for situations where bird counts are less than 10.

For binomial models, we considered relative odds which incorporated absolute probability estimates. Fig. 4 shows the association between power and the relative odds ratio calculated from the absolute probability estimates i.e. the logit of each estimate was calculated (probability / 1-probability) and the ratio of these logits was used in Fig. 4. For example, a species with an estimated probability of occurrence of 0.50 on one treatment and 0.25 on the other treatment has logits of 1 and 0.33 respectively and therefore a relative odds ratio of 3. But this value can be obtained from the whole range of probabilities, so general conclusions can be drawn from Fig. 4 despite the wide range in variation of observed probabilities. For 40-60 sites an odds ratio of 8.58 would be needed to achieve 90% power, so in the above example, probabilities of 0.25 and 0.50 would not be sufficient to achieve 90% power. For 61-80 sites a lower relative odds ratio of 5.42 would be needed. With a higher sample size (81-100 sites) this value was reduced to 4.80. Note that there is a far greater amount of scatter in Fig. 4 relative to Fig. 3, indicating greater influence of original sample sizes, proportion of simulated data sets failing to produce valid models and absolute magnitude of probability estimates derived.

7. DISCUSSION

The most powerful analyses of bird and mammal occurrence on the FSE involved the LATE data set, i.e. a comparison of GMHT treated crop with conventionally treated crop. Point counts collecting foraging data were most likely to yield analyses of high power in this LATE data set. Results for sugar beet and particularly oilseed rape were of relatively low power in comparison with results from maize. The species where 90% power was predicted to be achieved given the combined sample sizes for the FSE in 2000 and 2001 were Red-Legged Partridge, Swallow, Dunnock, Wren, Whitethroat, Blackbird, Chaffinch and Yellowhammer. In order to achieve a power of 90%, we predict that for a any Poisson model, approximately 115-125% difference in numbers (i.e. more than double) between treatments would be required for sample sizes of between 40 and 80 sites, and a 90% difference in numbers for 81-100 sites. These estimates are for small bird counts (<10 per visit) and may not be applicable to situations were many more birds are recorded. For binomial models, the odds ratio derived from probability of occurrence would need to be approximately 9 times greater on one treatment to achieve 90% power for a sample of 40 to 60 sites and approximately 5-5.5 times greater for 61-100 sites.

Rabbit presence on sugar beet crops provided the most powerful analysis for mammals, and sample sizes required to achieve 90% power were already achieved (i.e. < 24). Mammals were recorded when detected during the course of bird surveys and no attempt was made to survey mammals specifically. It should be borne in mind that the methods used may not have been sufficient to adequately survey mammals. A specifically designed survey is needed to adequately determine the potential of surveying mammals to detect effects of GMHT crops.

The species-specific analysis presented in this paper is reliant on the very important assumption that the observed parameter estimates (Appendix 1) will be the true parameter estimates across a range of sample sizes. These estimated parameter estimates would be expected to be more accurate as sample sizes in the original model increase. If we consider the species yielding the most powerful models in Table 4, we actually find that in all species, the original model was based on sample sizes of 6 or fewer sites (Appendix 1), with one exception, Red-Legged Partridge, which was detected on between 14-16 sugar beet sites. For the majority of species, the assumption can therefore be regarded as tenuous. Data from further sites could be used to test this assumption, but due to the high proportion of sites where no birds of most individual species were recorded, this is likely to take a large effort to produce adequate sample sizes. For example, for foraging Yellowhammers on maize crops, an estimated total of 66 sites would have to be surveyed to achieve a sample size of 24 sites with birds. The combined number of maize sites for 2000 and 2001 is someway short of this total at 39.

A potential way of increasing sample sizes and therefore increasing our confidence in the representativeness of derived parameter estimates is to combine data from different crops. However, there are sound biological reasons why crops should be analysed separately. First, we know from previous studies that birds use crops in different ways and sometimes show marked preferences for particular crops (see numerous papers in Aebischer et al. 2000). Second, the spraying regimes differ markedly from crop to crop, both in terms of conventional and GMHT management. Third, different crops will obviously differ in vegetation structure and this may affect the detectability of birds.

The analyses undertaken considered a range of different measures, including bird abundance, bird presence/absence, foraging events and number of foragers. The largest sample sizes were from bird registrations, and presence/absence of registrations, in both fields and adjacent field boundaries. For that reason, this may be considered as a good candidate for future research. However, for many species, the majority of records were in adjacent boundaries and not in fields (compare sample sizes for the two habitats in Appendix 1), so it is questionable whether the treatment could really be having any effect in these cases. Although the experimental set-up and pairing procedure should have eliminated general systematic bias in boundary characteristics across treatments, there may still have been effects of boundary characteristics for individual species. Further more complex analyses identifying these factors and incorporating them into models would be required if we were to determine the effects of these variables.

The data sets pertaining only to the fields tended to have smaller sample sizes, but they generally produced analyses of highest power (Table 4). For the foraging data sets this may be expected as this generally had more data (in terms of actual counts per site rather than the number of sites). The foraging data set in particular provides some interesting results as we may expect that food abundance or availability would be the factors affected most by GMHT treatments. We may also expect less of an influence of boundary habitats with this data set. Therefore, any measure of feeding would be more likely to produce significant differences. The analysis of foraging events is reliant on the assumption that this measure can be used as an indirect measure of food availability irrespective of the independence of the data points. The number of individuals foraging was a more stringent measure of foraging, yet analyses involving this variable did not have appreciably lower power.

The data can be used to make general inferences about the magnitude of parameter estimates and the number of sites needed to be surveyed to achieve a given level of power. We predict that a power of 90% could be achieved if the magnitude of the difference in bird abundance (or any other count measure) between treatments was greater than approximately 125% for Poisson models, or if the odds ratio derived from estimated probability of bird presence was approximately 9 times greater on one treatment for binomial models in samples with 40 to 60 sites (the likely range of sample sizes when additional sites are included in the subsequent year will be 39 to 50). Throughout this study, we have used a stringent level of power of 90%, but if a lower level of power were considered acceptable, the sample sizes and the magnitude of differences required to achieve this level would be lower. For example, a further 9 species/crop/variable specific data sets could provide analyses of sufficient power if we considered a 75% level of power to be acceptable (i.e. there would be 9 more rows in Tables 2 and 3 combined).

In summary, the analyses have indicated that a high probability of detecting significant differences in bird abundance or occurrence between treatments would be possible for several species in certain crops with the additional sites due to be surveyed in this coming spring/summer. A further year of fieldwork is also planned for 2002, but the number of participating sites has yet to be decided. If we assume that the same number of sites will be surveyed in 2002 as is planned for 2001, then the analyses predict that a further 20 species/crop/variable specific data sets could provide analyses of sufficient power. Maize crops are likely to yield the most powerful analyses and efforts should be made to concentrate fieldwork into the later half of the breeding season after GM herbicides have been applied. A point count survey recording foraging individuals is likely to be the best method both for

statistical and biological reasons. Detection of significant differences in mammal abundance were less likely.

The above findings are dependent on acceptance of the assumption that derived parameter estimates are likely to remain more-or-less the same when further sites are surveyed, i.e. the current (sometimes small) sample is representative of any proposed larger sample. Due to the small sample sizes and therefore the questionable realism of parameter estimates, we suggest that the analysis presented in this paper should be used as a baseline to direct future studies rather than be used as a definitive statement of the power of the current GMHT trials to detect differences in bird abundance. For example, these results have indicated that foraging birds do show sometimes considerable differences between treatments, but rigorous experimental work on foraging birds, rather than bird surveys, may yield more valuable results.

Acknowledgements

Table 1   A summary of the data sets analysed in power analyses.

Analysis variable	Sampling unit	Model error structure
Bird registrations	field + boundary	Poisson
	field	Poisson
Presence of a bird species	field + boundary	Binomial
	field	Binomial
Foraging events	field	Poisson
No. individual foragers	field	Poisson
Foraging passes of aerial feeders	field	Poisson
Maximum no. individual aerial feeders	field	Poisson
Mammal registrations	field	Poisson
Presence of a mammal species	field	Binomial

Table 2 The power to detect significant differences in bird occurrence between treatment types for the parameter estimates for the WHOLE data set given in Appendix 1 given the original sample size. The number of sites (n) required to achieve 90% power is also given. Only those species where less than 100 sites were required to achieve at least 90% power are shown. (Note that the number of sites for 2000 + those planned to be part of FSE in 2001 is 50 for sugar beet, 39 for maize and 37 for rape).

Crop	Species	Variable	Model	Habitat	Power (%)	n for 90% power
Beet	Red-Legged Partridge	Count	Poisson	Field	87.8	90
	Red-Legged Partridge	Count	Poisson	Field + boundary	95.3	<24
	Yellowhammer	Foraging events	Poisson	Field	97.7	<24
Maize	Dunnock	Count	Poisson	Field + boundary	74.7	58
	Whitethroat	Count	Poisson	Field + boundary	85.5	15
	Whitethroat	Presence	Binomial	Field + boundary	60.8	84
	Dunnock	Foraging events	Poisson	Field	82.2	32
	Chaffinch	Foraging events	Poisson	Field	67.8	39
	Yellowhammer	Foraging events	Poisson	Field	73.3	39
Rape	Skylark	Presence	Binomial	Field + boundary	35.9	69
	Dunnock	Foraging events	Poisson	Field	77.0	39
	Chaffinch	Foraging events	Poisson	Field	90.6	<10

Table 3 The power to detect significant differences in bird occurrence between reatment types where the data have been divided into EARLY (conventional vs unsprayed GM) and LATE (conventional vs sprayed GM). Other details as in Table 2.

(a) EARLY data set

Crop	Species	Variable	Model	Habitat	Power (%)	n for 90% power
Beet	Dunnock	Presence	Binomial	Field + boundary	55.0	83
	Chaffinch	Count	Poisson	Field + boundary	41.6	72
	Yellowhammer	Presence	Binomial	Field	54.2	94
	Yellowhammer	Presence	Binomial	Field + boundary	63.4	62
Maize	Blackbird	Count	Poisson	Field	77.1	28
	Blackbird	Presence	Binomial	Field	72.6	30
	Blackbird	Count	Poisson	Field + boundary	39.9	59
	Blackbird	Foraging events	Poisson	Field	45.0	42
	Blackbird	Maximum individuals	Poisson	Field	47.3	37
	Chaffinch	Foraging events	Poisson	Field	25.8	98
Rape	Skylark	Count	Poisson	Field + boundary	18.4	90

(b) LATE data set

Crop	Species	Variable	Model	Habitat	Power (%)	n for 90% power
Beet	Red-Legged Partridge	Count	Poisson	Field	81.9	35
	Red-Legged Partridge	Count	Poisson	Field + boundary	88.0	38
	Dunnock	Presence	Binomial	Field + boundary	53.4	64
	Wren	Foraging events	Poisson	Field	85.9	50
	Wren	Count	Poisson	Field + boundary	36.9	72
	Blackbird	Foraging events	Poisson	Field	85.7	38
	Blackbird	Maximum foragers	Poisson	Field	52.1	63
	Yellowhammer	Count	Poisson	Field	55.5	65
	Yellowhammer	Presence	Binomial	Field + boundary	46.7	70
	Yellowhammer	Foraging events	Poisson	Field	60.7	61
Maize	Skylark	Count	Poisson	Field + boundary	28.2	71
	Swallow	Foraging passes	Poisson	Field	99.9	<24
	Swallow	Maximum foragers	Poisson	Field	74.5	26
	Dunnock	Presence	Binomial	Field + boundary	48.5	37
	Dunnock	Foraging events	Poisson	Field	51.1	50
	Dunnock	Maximum foragers	Poisson	Field	44.2	34
	Wren	Count	Poisson	Field + boundary	43.6	38
	Wren	Presence	Binomial	Field + boundary	59.3	33
	Whitethroat	Count	Poisson	Field + boundary	87.6	19
	Whitethroat	Presence	Binomial	Field + boundary	74.8	32
	Robin	Presence	Binomial	Field + boundary	34.9	84
	Chaffinch	Foraging events	Poisson	Field	37.7	64
	Yellowhammer	Binomial	Presence	Field	86.5	21
	Yellowhammer	Count	Poisson	Field + boundary	52.6	30
	Yellowhammer	Presence	Binomial	Field + boundary	65.9	28
	Yellowhammer	Foraging events	Poisson	Field	64.5	32
	Yellowhammer	Maximum foragers	Poisson	Field	56.9	33
Rape	Swallow	Maximum foragers	Poisson	Field	34.9	58
	Whitethroat	Count	Poisson	Field + boundary	39.1	41
	Whitethroat	Presence	Binomial	Field + boundary	42.7	39
	Blackbird	Presence	Binomial	Field	45.4	42
	Blackbird	Count	Poisson	Field + boundary	33.6	63
	Chaffinch	Count	Poisson	Field + boundary	43.3	45
	Yellowhammer	Count	Poisson	Field + boundary	21.9	85
	Yellowhammer	Presence	Binomial	Field + boundary	26.3	81

Table 3   Continued.

Table 4   Species that would achieve 90% power with extra FSE sites for the 2001 breeding season (i.e. total for 2000 + total for 2001). These assume that observed differences between GMHT and conventional treatments detected in the original models (Appendix 1) will have the same mean when further sites are added. Bird presence was modelled with binomial logistic regression. Other dependent variables were modelled with Poisson regression.

Crop	Combined sites 2000+2001	Data set	Species	Dependent variable	Habitat
Beet	50	WHOLE	Red-Legged Partridge	Count	Field
			Red-Legged Partridge	Count	Field + boundary
Maize	39		Whitethroat	Count	Field + boundary
			Dunnock	Foraging events	Field
			Chaffinch	Foraging events	Field
			Yellowhammer	Foraging events	Field
Maize	39	EARLY	Blackbird	Count	Field
			Blackbird	Presence	Field
			Blackbird	Maximum foragers	Field
Beet	50	LATE	Red-Legged Partridge	Count	Field
			Red-Legged Partridge	Count	Field + boundary
			Blackbird	Foraging events	Field
Maize	39		Swallow	Foraging passes	Field
			Swallow	Maximum foragers	Field
			Dunnock	Presence	Field + boundary
			Dunnock	Maximum foragers	Field
			Wren	Count	Field + boundary
			Wren	Presence	Field + boundary
			Yellowhammer	Count	Field + boundary
			Yellowhammer	Presence	Field
			Yellowhammer	Foraging events	Field
			Yellowhammer	Maximum foragers	Field

Table 5   The power to detect significant differences in mammal occurrence between treatment types for the parameter estimates given in Appendix 2 given the original sample size. The number of sites (n) required to achieve 90% power is also given. Only those species where less than 100 sites were required to achieve at least 90% power are shown.

Data set	Species	Crop	Model	Power (%)	n for 90% power
WHOLE	Rabbit	Beet	Binomial	99.3	<24
EARLY	Hare	Rape	Poisson	32.6	80
LATE	Rabbit	Beet	Poisson	61.4	69
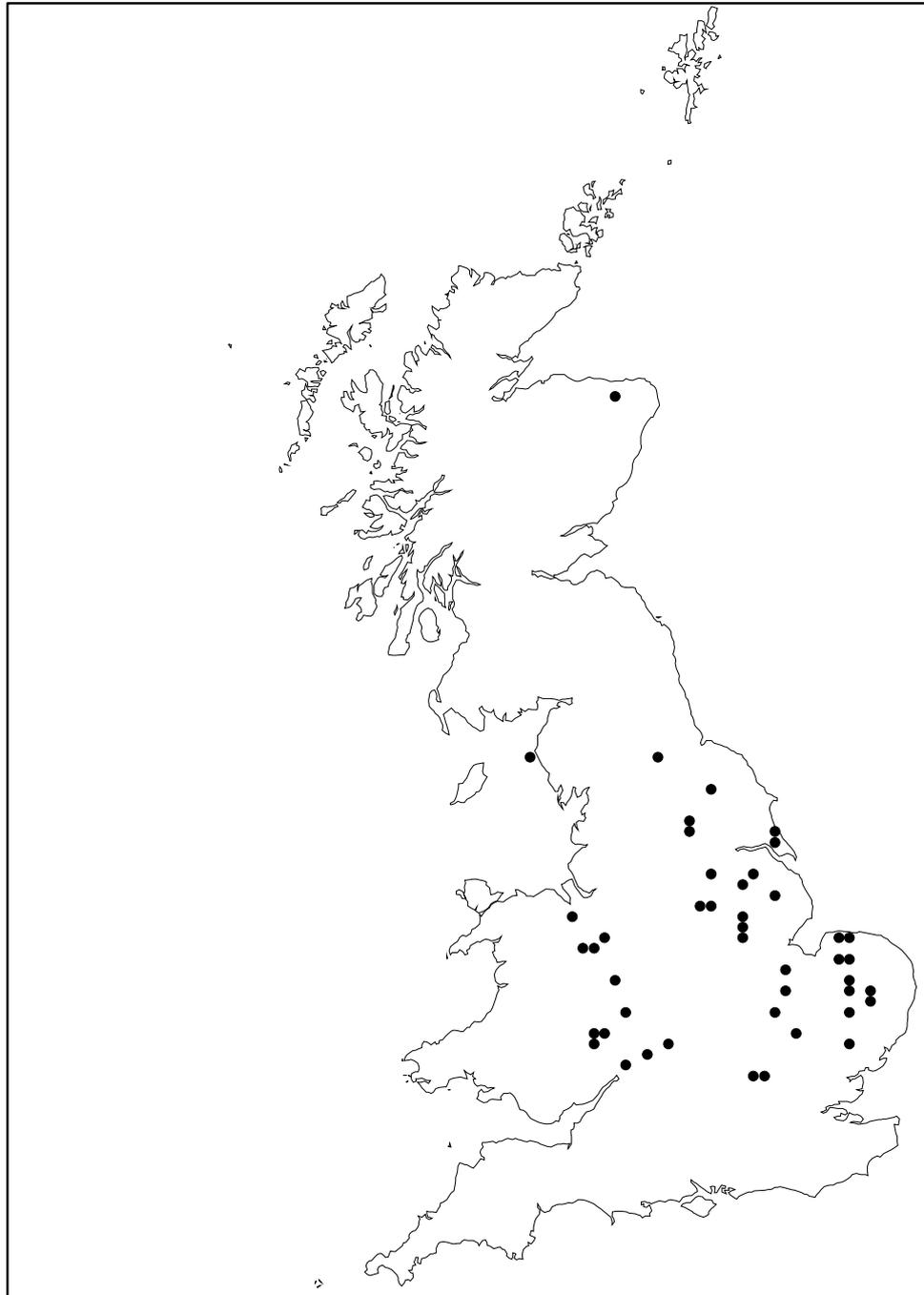
Figure 1   The distribution of sugar beet, maize and spring rape GMHT trial sites in Great Britain where bird surveys were undertaken. Note that in some cases, more than one trial site was in a 10-km square. The locations of these have been moved by 10-km for presentational purposes (10 sites).
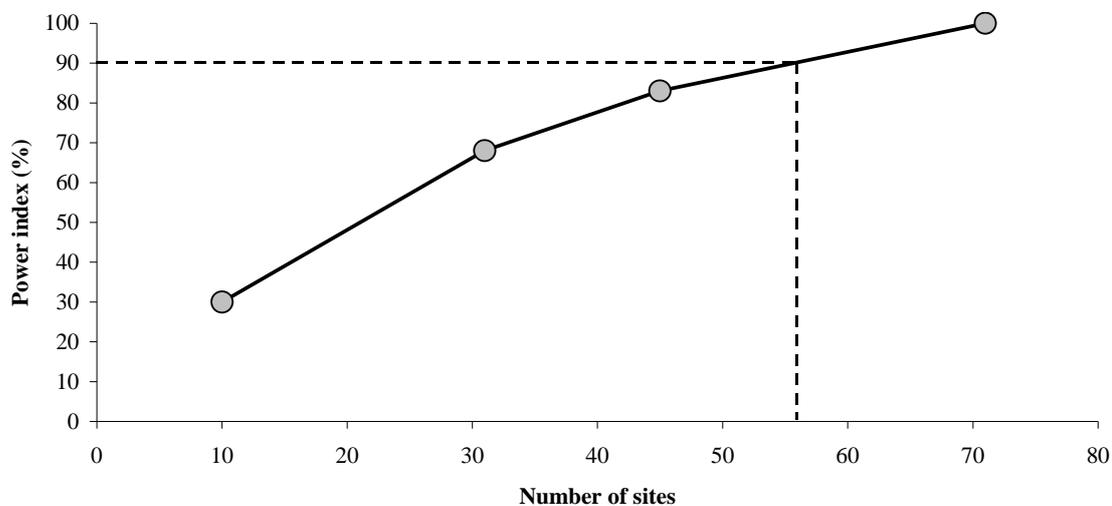
Figure 2   An example of the determination of the number of sites needed to achieve a given power. The circles indicate the power index (the statistical power adjusted for sample size) for 10, 29, 45 and 72 sites. The number of sites required to achieve 90% power index is shown by the dashed lines which in this case is predicted to be 56 sites.

(a) 40-60 sites

(b) 61-80 sites

(c) 81-100 sites
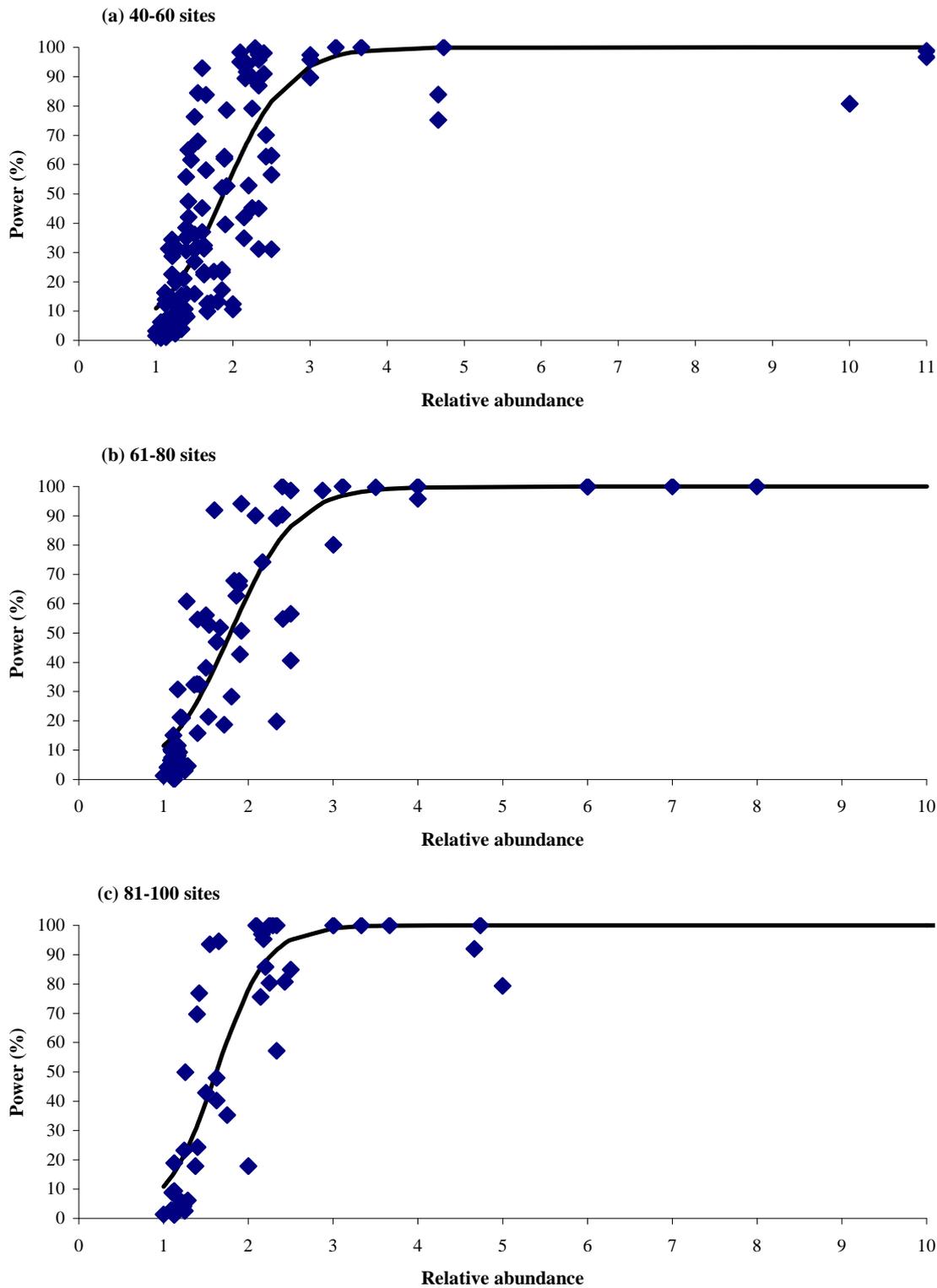
Figure 3   Power expressed as a percentage of significant treatment effects (in the same direction as parameter estimates in the original model) out of 1000 simulated data sets plotted against the relative difference in abundance between treatments. Each point represents a species for any Poisson model with additional sites. Three different scenarios are shown based upon sample sizes adjusted for the proportion of sites with no birds recorded, i.e. the power is based upon the total effort required for additional sites, rather than the actual number of sites in the model. Logistic curves were fitted to the data using general linear models with a logit link function. (a) 40-60 sites, logit(power) = 2.39*abundance – 4.49; (b) 61-80 sites, logit(power) = 2.59*abundance – 4.63; (c) 81-100 sites, logit(power) = 3.38*abundance – 5.48.

(a) 40-60 sites

(b) 61-80 sites

(c) 81-100 sites
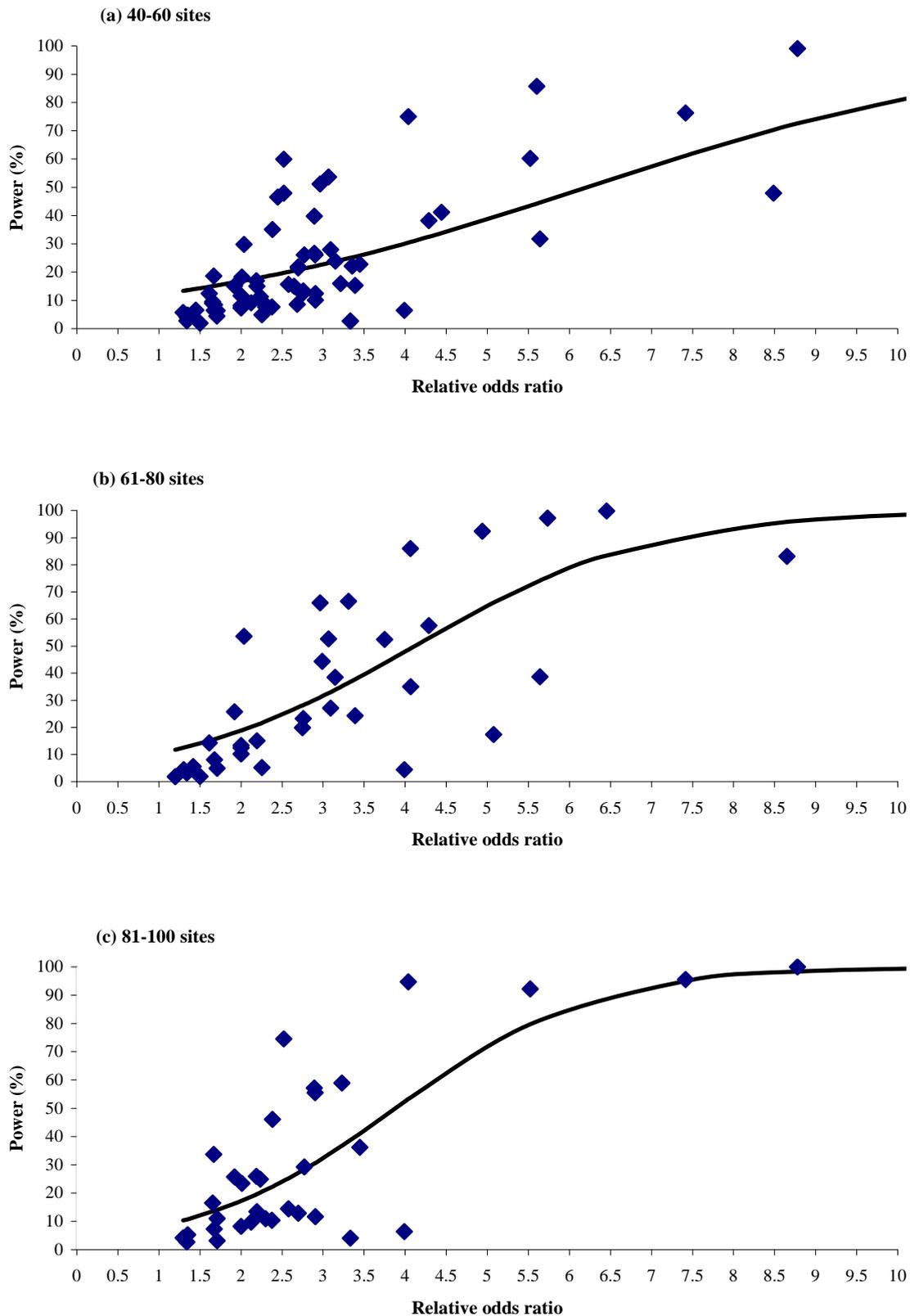
Figure 4   Power plotted against the relative odds ratio derived from binomial probabilities of bird occurrence on either treatment. Apart from using binomial models, the data sets used and determination of sample sizes were identical to that used in Fig. 3. Logistic curves were fitted to the data using general linear models with a logit link function (a) 40-60 sites, logit(power) = 0.38*[odds ratio] – 2.36; (b) 61-80 sites, logit(power) = 0.69*[odds ratio] – 2.84; (c) 81-100 sites, logit(power) = 0.86*[odds ratio] – 3.24.

A summary of Poisson and binomial models considering the effects of GMHT and conventional crop management on bird abundance and probability of occurrence in three different crop types. Analyses from three different data sets (WHOLE, EARLY and LATE) are given. Within each data set, models have been run on data from fields-only and on data from fields and adjacent field boundaries. Additionally, foraging events in fields and maximum abundance of aerial feeders in fields have been analysed (the latter for the LATE data set only). The number of sites indicates the number where at least one individual of the species in question was recorded. Total number of sites surveyed were 24 for sugar beet, 11 for maize and 10 for rape. The dispersion is calculated as deviance / degrees of freedom. Parameter estimates are for the treatment effect and are given as untransformed means ± standard error, relative to 0. The treatment used as the reference habitat (i.e. mean = 0) was randomly assigned. Asterisks indicate a significant change in deviance when the treatment term was added to the effects of site, where * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ (χ^2 test).

(a) WHOLE data set - Registrations in fields

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	16	2.09	0.770 ± 0.349*
Skylark	No. birds	Poisson	Beet	16	0.88	0.123 ± 0.202
Dunnock	No. birds	Poisson	Beet	5	1.67	0.847 ± 0.690
Blackbird	No. birds	Poisson	Beet	13	1.77	0.098 ± 0.256
Chaffinch	No. birds	Poisson	Beet	8	0.96	2.303 ± 1.049**
Yellowhammer	No. birds	Poisson	Beet	7	1.72	0.251 ± 0.504
Skylark	No. birds	Poisson	Maize	5	1.55	0.118 ± 0.486
Blackbird	No. birds	Poisson	Maize	6	0.37	0.762 ± 0.458
Yellowhammer	No. birds	Poisson	Maize	4	1.91	1.792 ± 1.494
Skylark	No. birds	Poisson	Rape	6	3.32	0.353 ± 0.256
Blackbird	No. birds	Poisson	Rape	4	2.26	0.288 ± 0.764
Yellowhammer	No. birds	Poisson	Rape	5	1.71	0.223 ± 0.671
Red-Legged Partridge	Presence/absence	Binomial	Beet	16	0.94	0.565 ± 0.407
Skylark	Presence/absence	Binomial	Beet	16	0.77	0.146 ± 0.383
Dunnock	Presence/absence	Binomial	Beet	5	1.41	1.357 ± 0.897
Blackbird	Presence/absence	Binomial	Beet	13	0.94	0.285 ± 0.473
Chaffinch	Presence/absence	Binomial	Beet	8	0.92	2.113 ± 1.095*
Yellowhammer	Presence/absence	Binomial	Beet	7	1.44	0.198 ± 0.631
Skylark	Presence/absence	Binomial	Maize	5	1.66	0.000 ± 0.726
Blackbird	Presence/absence	Binomial	Maize	6	0.42	0.803 ± 0.649
Yellowhammer	Presence/absence	Binomial	Maize	4	1.90	1.586 ± 1.178
Skylark	Presence/absence	Binomial	Rape	6	1.49	0.613 ± 0.559
Blackbird	Presence/absence	Binomial	Rape	4	1.82	0.827 ± 0.941
Yellowhammer	Presence/absence	Binomial	Rape	5	1.21	1.118 ± 0.918

(b) WHOLE data set - Registrations in fields and boundaries

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	16	2.15	0.779 ± 0.228
Skylark	No. birds	Poisson	Beet	17	1.15	0.154 ± 0.197
Wren	No. birds	Poisson	Beet	14	3.33	0.217 ± 0.234
Dunnock	No. birds	Poisson	Beet	14	1.99	0.211 ± 0.326
Whitethroat	No. birds	Poisson	Beet	11	2.45	0.642 ± 0.391
Robin	No. birds	Poisson	Beet	12	1.33	0.651 ± 0.356
Blackbird	No. birds	Poisson	Beet	15	3.61	0.189 ± 0.186
Chaffinch	No. birds	Poisson	Beet	13	2.51	0.154 ± 0.249
Yellowhammer	No. birds	Poisson	Beet	13	1.58	0.087 ± 0.295
Skylark	No. birds	Poisson	Maize	5	1.79	0.318 ± 0.465
Dunnock	No. birds	Poisson	Maize	6	1.64	1.540 ± 0.815*
Whitethroat	No. birds	Poisson	Maize	5	3.44	2.398 ± 1.370*
Robin	No. birds	Poisson	Maize	5	2.17	0.693 ± 0.707
Blackbird	No. birds	Poisson	Maize	8	1.54	0.470 ± 0.329
Chaffinch	No. birds	Poisson	Maize	9	2.27	0.125 ± 0.354
Yellowhammer	No. birds	Poisson	Maize	6	3.95	0.887 ± 0.449
Skylark	No. birds	Poisson	Rape	7	4.17	0.331 ± 0.248
Dunnock	No. birds	Poisson	Rape	5	5.71	0.486 ± 0.449
Wren	No. birds	Poisson	Rape	4	3.04	0.511 ± 0.730
Whitethroat	No. birds	Poisson	Rape	6	2.07	0.223 ± 0.474
Robin	No. birds	Poisson	Rape	5	1.15	0.001 ± 0.707
Blackbird	No. birds	Poisson	Rape	8	3.85	0.619 ± 0.469
Chaffinch	No. birds	Poisson	Rape	7	3.21	0.064 ± 0.359
Yellowhammer	No. birds	Poisson	Rape	7	4.07	0.043 ± 0.292

(b) Continued.

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	Presence/absence	Binomial	Beet	16	0.89	0.727 ± 0.388
Skylark	Presence/absence	Binomial	Beet	17	1.07	0.064 ± 0.348
Wren	Presence/absence	Binomial	Beet	14	2.43	0.593 ± 0.417
Dunnock	Presence/absence	Binomial	Beet	14	1.77	0.488 ± 0.466
Whitethroat	Presence/absence	Binomial	Beet	11	2.17	0.822 ± 0.498
Robin	Presence/absence	Binomial	Beet	12	1.35	0.326 ± 0.468
Blackbird	Presence/absence	Binomial	Beet	15	2.87	0.000 ± 0.362
Chaffinch	Presence/absence	Binomial	Beet	13	1.95	0.270 ± 0.425
Yellowhammer	Presence/absence	Binomial	Beet	13	1.43	0.372 ± 0.434
Skylark	Presence/absence	Binomial	Maize	5	1.89	0.438 ± 0.666
Dunnock	Presence/absence	Binomial	Maize	6	1.85	0.642 ± 0.665
Whitethroat	Presence/absence	Binomial	Maize	5	2.68	3.491 ± 2.203*
Robin	Presence/absence	Binomial	Maize	5	2.23	0.617 ± 0.800
Blackbird	Presence/absence	Binomial	Maize	8	1.73	0.151 ± 0.549
Chaffinch	Presence/absence	Binomial	Maize	9	1.78	0.279 ± 0.529
Yellowhammer	Presence/absence	Binomial	Maize	6	3.66	1.441 ± 1.222
Skylark	Presence/absence	Binomial	Rape	7	2.23	0.924 ± 0.526
Dunnock	Presence/absence	Binomial	Rape	5	4.11	0.187 ± 0.612
Wren	Presence/absence	Binomial	Rape	4	1.90	0.897 ± 0.799
Whitethroat	Presence/absence	Binomial	Rape	6	1.32	0.567 ± 0.622
Robin	Presence/absence	Binomial	Rape	5	1.65	0.283 ± 0.755
Blackbird	Presence/absence	Binomial	Rape	8	2.85	0.587 ± 0.548
Chaffinch	Presence/absence	Binomial	Rape	7	2.73	0.140 ± 0.529
Yellowhammer	Presence/absence	Binomial	Rape	7	2.82	0.839 ± 0.540

(c) WHOLE data set - Foraging birds

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Skylark	Foraging events	Poisson	Beet	5	10.04	0.118 ± 0.889
Dunnock	Foraging events	Poisson	Beet	5	4.14	0.087 ± 0.850
Blackbird	Foraging events	Poisson	Beet	6	3.03	0.337 ± 0.417
Chaffinch	Foraging events	Poisson	Beet	4	2.64	0.337 ± 0.952
Yellowhammer	Foraging events	Poisson	Beet	5	1.22	1.056 ± 0.453*
Dunnock	Foraging events	Poisson	Maize	5	3.06	0.811 ± 0.743
Blackbird	Foraging events	Poisson	Maize	4	2.53	0.110 ± 0.334
Chaffinch	Foraging events	Poisson	Maize	4	2.03	0.636 ± 0.587
Yellowhammer	Foraging events	Poisson	Maize	4	0.57	0.876 ± 0.401*
Skylark	Foraging events	Poisson	Rape	4	1.81	0.406 ± 0.465
Dunnock	Foraging events	Poisson	Rape	4	3.85	0.847 ± 0.958
Skylark	Max. no. birds	Poisson	Beet	5	4.43	0.194 ± 0.760
Dunnock	Max. no. birds	Poisson	Beet	5	3.85	0.000 ± 0.926
Blackbird	Max. no. birds	Poisson	Beet	6	2.96	0.424 ± 0.537
Chaffinch	Max. no. birds	Poisson	Beet	4	2.62	0.223 ± 1.086
Yellowhammer	Max. no. birds	Poisson	Beet	5	1.21	0.916 ± 0.532
Dunnock	Max. no. birds	Poisson	Maize	5	3.05	0.847 ± 0.853
Blackbird	Max. no. birds	Poisson	Maize	4	1.86	0.308 ± 0.360
Chaffinch	Max. no. birds	Poisson	Maize	4	2.24	0.539 ± 0.712
Yellowhammer	Max. no. birds	Poisson	Maize	4	0.42	0.588 ± 0.360
Skylark	Max. no. birds	Poisson	Rape	4	0.86	0.337 ± 0.384
Dunnock	Max. no. birds	Poisson	Rape	4	1.84	0.916 ± 0.803

(d) EARLY data set - Registrations in fields

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	8	1.88	0.789 ± 0.539
Skylark	No. birds	Poisson	Beet	11	0.81	0.094 ± 0.336
Blackbird	No. birds	Poisson	Beet	6	3.38	0.105 ± 0.460
Yellowhammer	No. birds	Poisson	Beet	4	1.80	1.609 ± 1.095
Blackbird	No. birds	Poisson	Maize	4	0.59	2.079 ± 1.061*
Skylark	No. birds	Poisson	Rape	4	2.99	0.375 ± 0.392
Red-Legged Partridge	Presence/absence	Binomial	Beet	8	2.33	0.648 ± 0.815
Skylark	Presence/absence	Binomial	Beet	11	1.25	0.000 ± 0.817
Blackbird	Presence/absence	Binomial	Beet	6	1.38	0.000 ± 0.894
Yellowhammer	Presence/absence	Binomial	Beet	4	2.57	2.069 ± 1.365
Blackbird	Presence/absence	Binomial	Maize	4	1.55	2.985 ± 1.503*
Skylark	Presence/absence	Binomial	Rape	4	2.73	1.195 ± 1.543

(e) EARLY data set - Registrations in fields and boundaries

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	9	1.44	0.619 ± 0.469
Skylark	No. birds	Poisson	Beet	12	1.08	0.084 ± 0.318
Wren	No. birds	Poisson	Beet	8	1.79	0.486 ± 0.450
Dunnock	No. birds	Poisson	Beet	7	1.30	0.560 ± 0.627
Robin	No. birds	Poisson	Beet	7	1.69	0.916 ± 0.592
Blackbird	No. birds	Poisson	Beet	9	4.53	0.095 ± 0.309
Chaffinch	No. birds	Poisson	Beet	9	2.05	0.651 ± 0.356
Yellowhammer	No. birds	Poisson	Beet	7	1.46	0.811 ± 0.601
Dunnock	No. birds	Poisson	Maize	4	2.06	$1.386 \pm 0.791*$
Blackbird	No. birds	Poisson	Maize	4	1.16	0.876 ± 0.532
Chaffinch	No. birds	Poisson	Maize	5	1.68	0.118 ± 0.486
Yellowhammer	No. birds	Poisson	Maize	6	2.14	0.406 ± 0.646
Skylark	No. birds	Poisson	Rape	4	3.33	0.435 ± 0.387
Red-Legged Partridge	Presence/absence	Binomial	Beet	9	1.45	1.035 ± 0.861
Skylark	Presence/absence	Binomial	Beet	12	1.54	0.000 ± 0.800
Wren	Presence/absence	Binomial	Beet	8	1.78	0.000 ± 0.894
Dunnock	Presence/absence	Binomial	Beet	7	1.36	1.638 ± 0.992
Robin	Presence/absence	Binomial	Beet	7	2.13	0.705 ± 0.851
Blackbird	Presence/absence	Binomial	Beet	9	3.25	0.305 ± 0.782
Chaffinch	Presence/absence	Binomial	Beet	9	2.12	0.000 ± 0.873
Yellowhammer	Presence/absence	Binomial	Beet	7	1.72	$2.019 \pm 1.020*$
Dunnock	Presence/absence	Binomial	Maize	4	1.58	0.913 ± 1.396
Blackbird	Presence/absence	Binomial	Maize	4	1.57	0.916 ± 1.396
Chaffinch	Presence/absence	Binomial	Maize	5	2.19	0.439 ± 0.943
Yellowhammer	Presence/absence	Binomial	Maize	6	1.66	0.416 ± 0.918
Skylark	Presence/absence	Binomial	Rape	4	2.73	1.954 ± 1.543

(f) EARLY data set - Foraging events

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Blackbird	Foraging events	Poisson	Maize	4	2.13	0.550 ± 0.473
Chaffinch	Foraging events	Poisson	Maize	4	2.27	0.486 ± 0.677
Blackbird	Max. foragers	Poisson	Maize	4	1.28	0.827 ± 0.514
Chaffinch	Max. foragers	Poisson	Maize	4	2.08	0.288 ± 0.780

(g) LATE data set - Registrations in fields

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	14	2.92	0.739 ± 0.271**
Skylark	No. birds	Poisson	Beet	14	0.92	0.227 ± 0.256
Dunnock	No. birds	Poisson	Beet	5	1.72	0.878 ± 0.691
Blackbird	No. birds	Poisson	Beet	11	2.15	0.095 ± 0.309
Yellowhammer	No. birds	Poisson	Beet	5	0.42	1.386 ± 0.791*
Skylark	No. birds	Poisson	Maize	4	2.03	0.511 ± 0.730
Blackbird	No. birds	Poisson	Maize	4	0.44	0.154 ± 0.556
Skylark	No. birds	Poisson	Rape	4	2.53	0.194 ± 0.631
Yellowhammer	No. birds	Poisson	Rape	4	1.91	0.288 ± 0.764
Red-Legged Partridge	Presence/absence	Binomial	Beet	14	1.21	0.563 ± 0.495
Skylark	Presence/absence	Binomial	Beet	14	0.99	0.248 ± 0.466
Dunnock	Presence/absence	Binomial	Beet	5	1.56	1.680 ± 0.993
Blackbird	Presence/absence	Binomial	Beet	11	1.24	0.418 ± 0.531
Yellowhammer	Presence/absence	Binomial	Beet	5	0.61	1.523 ± 0.949
Skylark	Presence/absence	Binomial	Rape	4	0.88	0.362 ± 0.854

(h) LATE data set - Registrations in fields and boundaries

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	14	3.00	0.827 ± 0.262**
Skylark	No. birds	Poisson	Beet	14	1.07	0.331 ± 0.248
Wren	No. birds	Poisson	Beet	14	2.77	0.501 ± 0.283
Dunnock	No. birds	Poisson	Beet	12	1.94	0.074 ± 0.385
Whitethroat	No. birds	Poisson	Beet	11	2.14	0.636 ± 0.412
Robin	No. birds	Poisson	Beet	9	2.17	0.486 ± 0.494
Blackbird	No. birds	Poisson	Beet	15	2.58	0.350 ± 0.235
Chaffinch	No. birds	Poisson	Beet	12	1.96	0.406 ± 0.373
Yellowhammer	No. birds	Poisson	Beet	10	1.58	0.431 ± 0.356
Skylark	No. birds	Poisson	Maize	4	2.27	0.847 ± 0.690
Wren	No. birds	Poisson	Maize	4	0.98	1.253 ± 0.802
Dunnock	No. birds	Poisson	Maize	4	0.99	1.792 ± 1.080*
Robin	No. birds	Poisson	Maize	4	1.50	1.099 ± 1.155
Blackbird	No. birds	Poisson	Maize	7	1.35	0.182 ± 0.428
Chaffinch	No. birds	Poisson	Maize	7	3.66	0.406 ± 0.527
Yellowhammer	No. birds	Poisson	Maize	5	2.51	1.299 ± 0.651
Skylark	No. birds	Poisson	Rape	5	2.57	0.118 ± 0.344
Whitethroat	No. birds	Poisson	Rape	5	1.99	1.099 ± 0.666
Blackbird	No. birds	Poisson	Rape	4	2.07	1.099 ± 0.817
Chaffinch	No. birds	Poisson	Rape	4	3.04	0.876 ± 0.532
Yellowhammer	No. birds	Poisson	Rape	5	3.11	0.435 ± 0.387

(h) Continued.

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	Presence/absence	Binomial	Beet	14	1.39	0.560 ± 0.478
Skylark	Presence/absence	Binomial	Beet	14	1.21	0.109 ± 0.466
Wren	Presence/absence	Binomial	Beet	14	2.50	0.806 ± 0.530
Dunnock	Presence/absence	Binomial	Beet	12	1.66	0.158 ± 0.563
Whitethroat	Presence/absence	Binomial	Beet	11	2.51	0.834 ± 0.592
Robin	Presence/absence	Binomial	Beet	9	1.98	0.590 ± 0.635
Blackbird	Presence/absence	Binomial	Beet	15	2.05	0.185 ± 0.430
Chaffinch	Presence/absence	Binomial	Beet	12	2.27	0.421 ± 0.533
Yellowhammer	Presence/absence	Binomial	Beet	10	1.55	0.322 ± 0.569
Skylark	Presence/absence	Binomial	Maize	4	2.33	0.000 ± 1.000
Wren	Presence/absence	Binomial	Maize	4	1.65	2.156 ± 1.042*
Dunnock	Presence/absence	Binomial	Maize	4	0.79	1.804 ± 1.247
Robin	Presence/absence	Binomial	Maize	4	1.72	1.316 ± 1.248
Blackbird	Presence/absence	Binomial	Maize	7	1.57	0.000 ± 0.718
Chaffinch	Presence/absence	Binomial	Maize	7	3.15	0.575 ± 0.768
Yellowhammer	Presence/absence	Binomial	Maize	5	2.25	2.099 ± 1.048
Skylark	Presence/absence	Binomial	Rape	5	0.97	0.643 ± 0.812
Whitethroat	Presence/absence	Binomial	Rape	5	1.93	1.499 ± 0.937
Blackbird	Presence/absence	Binomial	Rape	4	1.87	0.866 ± 0.962
Chaffinch	Presence/absence	Binomial	Rape	4	4.02	0.657 ± 0.821
Yellowhammer	Presence/absence	Binomial	Rape	5	2.57	0.903 ± 0.796

(i) LATE data set - Foraging birds

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Skylark	Foraging events	Poisson	Beet	5	9.07	0.091 ± 0.909
Dunnock	Foraging events	Poisson	Beet	5	5.52	0.606 ± 1.192
Blackbird	Foraging events	Poisson	Beet	6	4.11	1.135 ± 0.777
Yellowhammer	Foraging events	Poisson	Beet	5	1.10	0.916 ± 0.439*
Dunnock	Foraging events	Poisson	Maize	5	3.15	1.099 ± 1.024
Blackbird	Foraging events	Poisson	Maize	4	6.53	0.241 ± 0.728
Yellowhammer	Foraging events	Poisson	Maize	4	0.74	1.946 ± 0.917**
Skylark	Max. no. birds	Poisson	Beet	5	4.68	0.143 ± 0.820
Dunnock	Max. no. birds	Poisson	Beet	5	3.49	0.118 ± 0.908
Blackbird	Max. no. birds	Poisson	Beet	6	4.07	0.734 ± 0.709
Yellowhammer	Max. no. birds	Poisson	Beet	5	1.19	0.773 ± 0.539
Dunnock	Max. no. birds	Poisson	Maize	5	3.05	0.847 ± 0.853
Blackbird	Max. no. birds	Poisson	Maize	4	3.72	0.140 ± 0.590
Yellowhammer	Max. no. birds	Poisson	Maize	4	0.64	1.792 ± 0.865*

(j) LATE data set - Aerial feeders

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Swallow	No. foraging events	Poisson	Beet	6	4.17	0.197 ± 0.574
Swallow	Max. no. birds	Poisson	Beet	6	1.58	0.167 ± 0.514
Swallow	No. foraging events	Poisson	Maize	5	10.55	1.555 ± 0.923
Swallow	Max. no. birds	Poisson	Maize	5	3.93	1.204 ± 0.923
Swallow	No. foraging events	Poisson	Rape	4	1.30	0.229 ± 0.258
Swallow	Max. no. birds	Poisson	Rape	4	0.30	0.470 ± 0.179**

APPENDIX 2

A summary of Poisson and binomial models considering the effects of GMHT and conventional crop management on mammal abundance and probability of occurrence in three different crop types. Analyses from three different data sets (WHOLE, EARLY and LATE) are given. The number of sites indicates the number where at least one individual of the species in question was recorded. Total number of sites surveyed were 24 for sugar beet, 11 for maize and 10 for rape. The dispersion is calculated as deviance / degrees of freedom. Parameter estimates are for the treatment effect and are given as untransformed means ± standard error, relative to 0. The treatment used as the reference habitat (i.e. mean = 0) was randomly assigned. Asterisks indicate a significant change in deviance when the treatment term was added to the effects of site and date, where * $P < 0.05$ (^{2} test).

(a) WHOLE data set

Species	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Rabbit	Poisson	Beet	7	0.51	1.050 ± 0.313***
Hare	Poisson		12	1.84	0.370 ± 0.281
Rabbit	Binomial		7	0.72	3.638 ± 0.970***
Hare	Binomial		12	1.83	0.492 ± 0.955
Hare	Poisson	Rape	5	0.73	0.435 ± 0.331
Hare	Binomial		5	0.44	0.000 ± 0.503

(b) EARLY

Species	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Hare	Poisson	Beet	8	1.97	0.363 ± 0.540
Hare	Binomial		8	1.38	0.526 ± 1.051

(c) LATE

Species	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Rabbit	Poisson	Beet	5	0.50	1.042 ± 0.335***
Hare	Poisson		10	1.37	0.442 ± 0.289
Rabbit	Binomial		5	0.70	0.544 ± 0.623
Hare	Binomial		10	0.95	0.711 ± 0.529

CHAPTER 2   USE OF GMHT CROPS BY BIRDS IN WINTER –
A POWER ANALYSIS

1.   SUMMARY

1. The introduction of Genetically Modified Herbicide Tolerant (GMHT) crops has the potential to markedly reduce the abundance of weed plants and hence the availability of weed seeds in post-harvest crops relative to non-GMHT crops. In order to assess the feasibility of using birds to compare GMHT and conventional crops in winter as part of a wider Farm-Scale Evaluation (FSE), we perform a power analysis on bird survey data collected from 69 experimental sites, divided equally into GMHT and conventional halves, in winter 2000/01.

2. Bird surveys were carried out between October and February and consisted of whole-area searches of birds using each field. A total of 23 former sugar beet fields, 11 former maize fields and 12 former spring oilseed rape fields were surveyed. Of these 25 were left as bare plough over the winter and 17 were left as stubble. Remaining sites were either planted with other crops or were dropped from the analysis because winter management was not exactly the same on either half of the field. Additionally, 23 winter oilseed rape fields were surveyed.

3. Poisson and binomial models were fitted to the data which incorporated site, date and treatment effects (GMHT or conventional). Models were derived for any species occurring on four or more sites. Models were run on separate crop types, firstly according to the former crop type and secondly according the current crop type. Parameter estimates for the treatment effect derived from the above models were used as the basis for a power analysis.

4. Several species were predicted to produce power of greater than 90% with less than 100 sites. Stubbles and former maize and sugar beet sites had the greatest number of species predicted to achieve this level of power (5, 4 and 4 species respectively). Crop types were not mutually exclusive, however, as the majority of maize and spring rape sites were left as stubble and the majority of sugar beet sites were left as bare plough.

5. Five species were predicted to achieve 90% power with the sample sizes expected to be part of the FSE in winter 2001/02. These were Pheasant, Skylark, Meadow Pipit, Blackbird and Linnet. Skylark was predicted to achieve 90% power on the most crop types.

6. We suggest that a winter survey of stubbles from former maize and spring rape crops is likely to yield analyses of sufficient power for Skylark, Blackbird (Poisson models) and Linnet (binomial models). Skylark was the best candidate for further research. It is unlikely that surveying other crops would provide a cost-effective means of assessing the effects of GMHT crop management on the abundance of birds in winter. The suitability of the FSE for assessing impacts of GMHT management on birds in winter would be greatly enhanced if the experimental design was such that all fields were left as stubbles and both GMHT and conventional halves were treated in the same way.

7.	Pilot work was also carried to assess the feasibility of measuring intake rates of foraging birds on the FSE sites through direct observation. This work suggests that, although collecting adequate data to estimate intake rates on GMHT and conventional field halves would require extensive fieldwork, it may be possible for a small number of species including skylark and yellowhammer using crop stubbles.

2. INTRODUCTION

Intake rates of granivorous birds in arable fields are related to the density and availability of seeds in the surface of the soil (Robinson & Sutherland 2000, Robinson 2001). The availability of seeds is typically highest on unsprayed stubble fields (Robinson 2001) and a number of granivorous bird species show significant preference for this habitat in winter (Wilson et al. 1996, Gillings & Fuller 2001). Declines in granivorous species may be associated with reduced survival outside the breeding season probably due to increased winter mortality (Peach et al. 1999, Siriwardena et al. 1999). This may be linked to decreases in the crops with the greatest weed seed densities and also in the availability of weed seeds (and also spilt cereal grain) within those crops (Robinson 2001) as a result of increased use of herbicides and improved harvesting techniques. Changes in weed seed availability may therefore explain population declines in certain species.

GMHT crops are likely to have lower weed abundance than conventional crops and consequently post-harvest seed availability is likely to be lower. Estimates by Robinson (2001) suggest that, for the Skylark at least, conventional stubbles may just have sufficient seed availabilities to meet daily energy requirements. A further reduction in seed availability may have significant impacts on quality of stubble as food resources for granivorous species, although this will depend on exactly how GMHT management is implemented (Watkinson et al. 2000).

The removal of weeds by herbicide treatments has been shown to have a negative impact on the abundance of several groups of invertebrates that depend on crop weeds for food and shelter in the summer (Potts 1986, Moreby & Southway 1999). The efficiency of weed eradication by GMHT treatment is likely to increase the impacts on invertebrate abundance in the summer. The importance of such impacts for the availability of invertebrates in the winter has yet to be considered, but the majority of omnivorous and invertebrate-feeding birds tend to feed on soil invertebrates rather than those on the surface. Negative effects of GMHT treatments on invertebrate feeders using crops post-harvest therefore seem less likely.

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3.   AIMS

The aims of this study were to assess the feasibility of carrying out further bird surveys on FSE sites in winter in order to test for effects of GMHT crops on bird abundance and foraging. The specific aims are therefore the same as in the previous report on summer bird occurrence (Chamberlain et al. 2002). These were: (i) to determine the number of experimental sites likely to be required in the FSE if statistically significant differences in bird occurrence (expressed using a variety of measures) are to be detected between GMHT and conventional crops in winter; and, (ii) to identify the crop types, species and methods which are likely to provide the most powerful tests of the influence of the use of GMHT versus conventional crops on bird occurrence in winter. (Note winter is used to describe the period October to February). As previously, different treatment types were not explicitly identified in the text and no conclusions were drawn on likely impacts of GMHT crops on bird occurrence from this study

4. METHODS

Bird surveys used the whole-area search method (Buckingham et al. 1999) and were only concerned with birds (of all species) actually using the crop. No field boundary survey was carried out as birds' foraging in boundaries is unlikely to be influenced greatly by crop management in winter (Siriwardena 2002). This involved walking parallel transects up and down the field (including the margins), the transects being close enough to ensure all birds were flushed. The maximum separation of transects was 50m, but this was reduced for taller crops (this was up to the judgement of individual surveyors). The location of all birds was recorded directly onto a field map using standard CBC activity codes. The map included the location of the strip separating the conventional and GMHT-treated halves of the field (this was not always evident in the field in the winter). Double counting individuals, when a bird is flushed from one part of a field to another, was avoided when possible. In these cases the initial location was recorded. In common with the breeding season survey, no data were collected in excessively wet or windy conditions. A total of 69 sites were surveyed, 23 sugar beet, 11 maize, 12 spring rape and 23 winter rape. Of these, 46 had previously been surveyed in the summer and 23 were new (all winter rape). The location of sites is shown in Fig. 1. Five visits were carried out (1 per month between October and February) on the majority of sites although there were 10 sites where no final visit was undertaken due to restrictions imposed by the foot and mouth disease outbreak.

The crop type (note the term 'crop type' is used in a broad sense to include stubble, fallow etc.) was recorded at each visit. The crop type typically varied over the course of the winter. For example, a number of sites began with sugar beet in October. This was harvested in the autumn and was left either as stubble or bare plough until late winter and in a few cases was sown with another crop (e.g. winter cereal). Note that this did not apply to winter rape crops all except one of which had already been sown by the start of the winter bird survey.

In addition to collection of bird count data, an attempt was made to determine intake rates of foraging birds in fields on a sub-set of the FSE sites. These findings are presented in a separate section of this report (Siriwardena 2002).

4.1 Analysis

Analytical methods followed those from the previous report (Chamberlain et al. 2002), taking parameter estimates for treatment effects (GMHT or conventional treatment in the previous summer) from both Poisson and binomial models which also included site effects and using these as a basis for a power analysis. However, for the winter data set, counts from each visit were considered as separate observations and date was included as an independent variable in the model. It was felt that seasonal effects were likely to be strong in the winter and that potential pseudoreplication in the data would be low as the majority of species are nomadic in the winter thus there is a low probability of re-sampling the same individuals. Considering the effects of GMHT application on bird use in these crops was not straightforward as there were two potential effects: that of GMHT management in the preceding summer and that of the current crop. Preliminary analyses indicated that bird abundance differed significantly according to both the current and previous crop for a number of species (a Poisson model including date, old crop type and current crop type showed that there were significant differences in bird abundance within both former and current crops for Woodpigeon, Skylark, Rook and Linnet and differences in one or other crop type for Red-Legged Partridge, Meadow Pipit, Pied Wagtail and Blackbird). We therefore analysed the data in two groups.

First, we considered differences between GMHT and conventionally treated halves of each field according to the crop in the summer (i.e three groups, sugar beet, spring rape and maize). Second, we considered treatment effects according to the current crop, taking the crop types with the largest sample sizes, stubble of any crop (n = 25 sites), bare plough (n = 17) and winter rape (n = 23). Note that samples were mutually exclusive within each group, but not between each group. The stubble sites were made up of three former sugar beet fields and seven fields each of former maize and spring rape crops. Bare plough sites were made up of 14 former sugar beet fields, 4 former maize fields, 6 former spring rape fields and 1 winter cereal field which was not sown until after the first survey visit. There were some cases where crop types differed between each treatment half on a given visit date, particularly sugar beet where 29% of visits (n = 109 visit days) had different crop types in each treatment half due to different harvesting dates. The figures were much lower for maize at 3.6% (55), spring rape at 10.9% (55), and winter rape at 5.6% (107). Data collected from these fields were not analysed.

5. RESULTS

5.1 Model Results

Parameter estimates and model dispersion (deviance / degrees of freedom) for species occurring on at least four sites are given in Appendix 1. There were no crops that had a noticeably higher or lower number of significant differences, although there was a higher proportion of significant differences in Poisson compared to binomial models. There were certain cases where Poisson model fits were very poor (very high dispersion) which was caused by a small number of very large flocks. These were likely to have influenced the parameter estimate and these poor model fits should be taken into account when interpreting results of the power analysis (see below).

5.2 Power Analysis

The power of the analyses and the number of sites required to achieve 90% power (determined using the method described in Chamberlain et al. 2002) are shown in Table 1 for those species where fewer than 100 sites would be required. A small number of species were predicted to achieve 90% power with under 100 sites considering only presence/absence (binomial models). These were Skylark and Blackbird on (former) maize crops and Linnet on (former) spring rape crops. There were more cases predicted to achieve 90% power with under 100 sites for Poisson models. Stubble crops had the greatest number of species listed, followed by (former) sugar beet and maize crops (Table 1). It should be noted that these crop types were not mutually exclusive: the majority of stubble crops had previously either been maize or spring rape and the majority of bare plough fields had previously been under sugar beet.

The species most commonly listed in Table 1 were Skylark and Woodpigeon (the most frequently occurring species). In certain cases of the Poisson models, caution should be taken when interpreting the power and sample sizes required to achieve 90% power due to poor fits in the original model (Appendix 1). For these species, parameter estimates have been used in simulations that may not be good approximations of mean abundance. Poor model fits have usually been caused by species that in most cases occur in small numbers (<10), but can form large flocks of several hundred birds. Parameter estimates may therefore be affected by a few extreme outliers. Furthermore, the simulation procedure is based only on this mean and the large flocks occurring in these species will not be adequately simulated as the procedure assumes a soundly fitting model. Such species include Red-Legged Partridge, Woodpigeon, Rook and Linnet. These species are listed in Table 1 to draw attention to the fact that they cannot be ruled out as candidates for further research, but the approach taken here is not adequate to draw conclusions for these species.

The number of sites of sugar beet, maize and spring rape planned to be part of the FSE in spring 2001 is known. The number of winter rape sites has yet to be confirmed, but we estimate the sample size will approximately double. Furthermore, an estimate of the number of stubble and bare plough sites present next winter has been made based on the current proportions of each crop that became either stubble or bare plough in winter 2000. The estimated sample sizes are 50 for sugar beet, 39 for maize, 37 for spring rape and is estimated to be 46 for winter rape, 53 for stubble and 64 for bare plough. The species that are estimated to achieve 90% power with FSE sites combined from both years can therefore be made based on Table 1, omitting species with poor model fits. These were Skylark, Blackbird (Poisson

model on former maize crops), Skylark, Blackbird (binomial model on former maize crop), Linnet (binomial model on former spring rape crop), Skylark (Poisson model on former spring rape crop), Skylark (Poisson model on winter rape crop), Pheasant, Meadow Pipit (Poisson model on bare plough) and Blackbird (Poisson model on stubble).

6.   DISCUSSION

The results of the power analysis showed that a number of species and a number of different crop types may achieve 90% power with a total sample size of under 100 sites. Of these, five species were predicted to achieve 90% power given the forecast number of sites expected to be part of the FSE that will be surveyed next winter (see above paragraph). These were Pheasant, Skylark, Meadow Pipit, Blackbird and Linnet.

Former and current crop types were often closely associated. For example, stubble and former maize, (64% of maize sites became stubble), stubble and former spring rape (58% of spring rape sites became stubble), bare plough and former sugar beet (61% of sugar beet sites became bare plough). Stubbles are preferred by a number of (mostly seed-eating) species (Wilson et al. 1996, Gillings & Fuller 2001) and the results for former maize and spring rape may reflect this (Table 1). However, the expectation that seed-eaters were likely to be most affected by GMHT treatments (see Introduction) and therefore will have the most powerful analyses was not really met. Of the five species predicted to achieve 90% power with additional sites, two species, Meadow Pipit and Blackbird, are largely restricted to invertebrates (at least when foraging in fields) in the winter. Little is known about the availability of invertebrates on arable fields outside the breeding season, so it is not possible to draw conclusions on the likelihood of effects of GMHT management on Meadow Pipits and Blackbirds. Pheasant, Skylark and Linnet have a granivorous diet, although as game species Pheasants are often supplied with cereal grain and are less closely associated with weedy stubbles than the latter two species. Skylark and Linnet may be the best candidates for study species as they are most likely to show a response to any differences in seed abundance that may be caused by GMHT crop management. Skylark in particular may be worth further consideration due to its abundance (it was one of the most commonly occurring species) and relatively high power in a range of crops. In addition, Skylark and Linnet are listed under both the UK Biodiversity Action Plans (Anon 1994, 1995) and as two of the species in the Farmland Bird Index (Gregory et al. 1999). An intensive study on intake rates in stubble fields from former maize and spring rape crops would enhance our ability to draw conclusions about likely effects of GMHT crops on winter feeding ecology (Bradbury 2002, Siriwardena 2002) and it would also greatly add to our knowledge of the winter feeding ecology of invertebrate feeders.

In conclusion, we predict that adequate power, taken as the 90% level, would be achievable if a repeat survey were carried out in the winter of 2001/02 for five species: Pheasant, Skylark, Meadow Pipit, Blackbird and Linnet. Skylark was the species that showed the most powerful analyses across a range of crops. This species may therefore be a good candidate for future intensive studies, including intake rates, on the effects of GMHT on winter feeding ecology. A winter survey of stubble fields is likely to yield the most powerful analyses and would also present the possibility of carrying out more intensive foraging observations (Siriwardena 2002). Future surveys should try to ensure that as many FSE sites as possible are left as stubbles to maximise sample sizes and hence the power to detect effects of GMHT management on birds in winter.

Table 1   The power to detect significant differences in bird occurrence between treatment types for the parameter estimates given in Appendix 1 given the original sample size. Species occurring on fewer than four sites were not considered. The number of sites (n) required to achieve 90% power is also given. Only those species where less than 100 sites were required to achieve at least 90% power are shown. (Note that the number of sites for 2000 + those planned to be part of FSE in 2001 is 50 for sugar beet, 39 for maize, 37 for spring rape and is estimated to be 46 for winter rape, 53 for stubble and 64 for bare plough). † indicates species that had high dispersion (deviance/df > 10) in the original models.

(a) Sugar beet (former crop)

Species	Model	Power (%)	n for 90% power
Red-Legged Partridge†	Poisson	100	<23
Pheasant	Poisson	48.2	62
Woodpigeon†	Poisson	100	<23
Yellowhammer	Poisson	62.2	67

(b) Maize (former crop)

Species	Model	Power (%)	n for 90% power
Woodpigeon†	Poisson	99.9	<11
Skylark	Poisson	57.3	34
Rook†	Poisson	99.9	<11
Blackbird	Poisson	91.4	<11
Skylark	Binomial	74.4	25
Blackbird	Binomial	78.6	22

(c) Spring rape (former crop)

Species	Model	Power (%)	n for 90% power
Skylark	Poisson	83.5	25
Linnet†	Poisson	99.9	<12

(d) Winter rape (current crop)

Species	Model	Power (%)	n for 90% power
Woodpigeon†	Poisson	99.9	<23
Skylark	Poisson	98.6	<23
Woodpigeon	Binomial	49.4	71

(e) Bare plough (current crop)

Species	Model	Power (%)	n for 90% power
Pheasant	Poisson	78.1	54
Meadow Pipit	Poisson	40.5	62

(f) Stubble (current crop)

| Species	Model	Power (%)	n for 90% power
Woodpigeon†	Poisson	99.9	<17
Skylark	Poisson	31.3	88
Rook†	Poisson	99.9	<17
Blackbird	Poisson	68.3	42
Linnet†	Poisson	99.9	<17
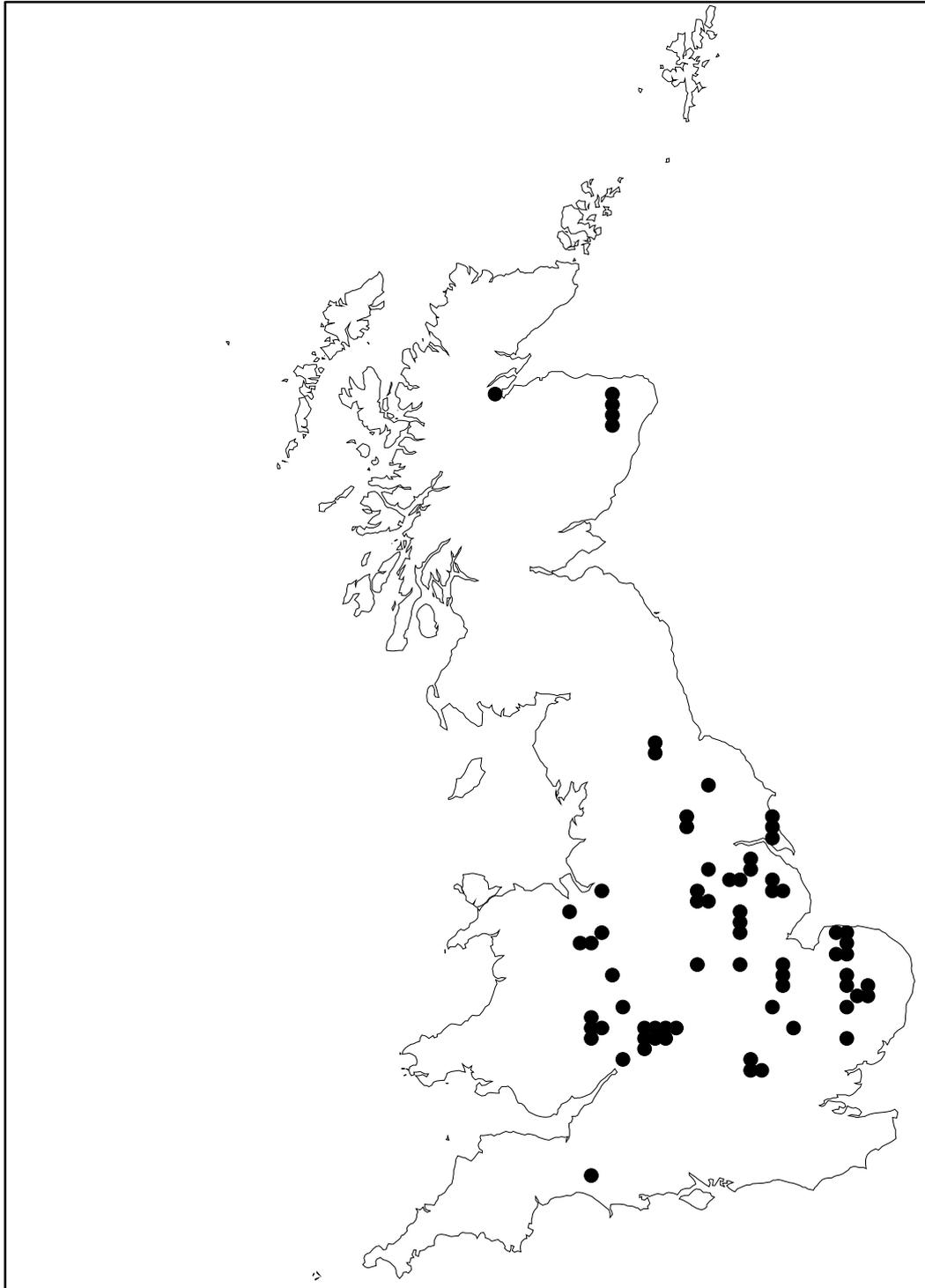
Figure 1 The distribution of GMHT trial sites in Great Britain where bird surveys were undertaken in winter 2000/01. Note that in some cases, more than one trial site was in a 10-km square. The locations of these have been moved by 10-km for presentational purposes (10 sites).

APPENDIX 1

A summary of Poisson and binomial models considering the effects of GMHT and conventional crop management on bird abundance and probability of occurrence in winter. The number of sites indicates the number where at least one individual of the species was recorded. Total number of sites surveyed were 23 for sugar beet, 11 for maize, 12 for spring rape and 23 for winter rape. Species occurring on fewer than four sites were not considered. For the former three crops, crop type refers to the crop that was present in the summer. Data were only included in the analysis if the following crop was the same on each side of a given experimental field. The dispersion is calculated as deviance / degrees of freedom. Parameter estimates are for the treatment effect and are given as untransformed means ± standard error, relative to 0. The treatment used as the reference habitat (i.e. mean = 0) was randomly assigned. Asterisks indicate a significant change in deviance when the treatment term was added to the effects of site and date, where * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ (χ^2 test).

(a) Poisson models

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	No. birds	Poisson	Beet	6	10.00	1.513 ± 0.217***
Pheasant	No. birds	Poisson	Beet	5	2.18	0.956 ± 0.526
Woodpigeon	No. birds	Poisson	Beet	7	11.84	0.798 ± 0.157***
Skylark	No. birds	Poisson	Beet	11	2.98	0.365 ± 0.260
Meadow Pipit	No. birds	Poisson	Beet	6	1.58	0.208 ± 0.373
Pied Wagtail	No. birds	Poisson	Beet	6	2.05	0.087 ± 0.417
Yellowhammer	No. birds	Poisson	Beet	4	0.78	2.397 ± 1.045**
Pheasant	No. birds	Poisson	Maize	5	1.36	0.442 ± 0.427
Woodpigeon	No. birds	Poisson	Maize	8	28.28	1.851 ± 0.119***
Skylark	No. birds	Poisson	Maize	5	1.56	1.030 ± 0.521*
Carrion Crow	No. birds	Poisson	Maize	6	0.76	0.223 ± 0.671
Rook	No. birds	Poisson	Maize	5	21.70	0.939 ± 0.141***
Blackbird	No. birds	Poisson	Maize	6	0.78	1.792 ± 0.624***
Yellowhammer	No. birds	Poisson	Maize	4	0.54	0.693 ± 0.707
Skylark	No. birds	Poisson	Spring rape	6	4.55	0.571 ± 0.200**
Linnet	No. birds	Poisson	Spring rape	8	25.78	0.462 ± 0.070***
Woodpigeon	No. birds	Poisson	Winter rape	11	39.34	0.481 ± 0.067***
Skylark	No. birds	Poisson	Winter rape	14	4.55	0.496 ± 0.122***

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Meadow Pipit	No. birds	Poisson	Winter rape	7	1.49	0.511 ± 2.990
Pied Wagtail	No. birds	Poisson	Winter rape	4	0.61	0.693 ± 0.866
Carrion Crow	No. birds	Poisson	Winter rape	6	2.66	0.463 ± 0.310
Pheasant	No. birds	Poisson	Stubble	5	1.62	0.074 ± 0.385
Woodpigeon	No. birds	Poisson	Stubble	10	30.66	0.995 ± 0.082***
Skylark	No. birds	Poisson	Stubble	9	2.73	0.360 ± 0.238
Pied Wagtail	No. birds	Poisson	Stubble	5	0.86	0.288 ± 0.540
Carrion Crow	No. birds	Poisson	Stubble	6	1.04	0.811 ± 0.601
Rook	No. birds	Poisson	Stubble	7	25.00	2.877 ± 0.224***
Blackbird	No. birds	Poisson	Stubble	5	0.66	1.705 ± 0.769**
Linnet	No. birds	Poisson	Stubble	8	21.32	0.777 ± 0.078***
Yellowhammer	No. birds	Poisson	Stubble	4	0.35	0.693 ± 0.866
Red-Legged Partridge	No. birds	Poisson	Bare	4	4.08	0.531 ± 0.399
Pheasant	No. birds	Poisson	Bare	5	1.57	1.946 ± 0.756**
Woodpigeon	No. birds	Poisson	Bare	6	8.25	0.017 ± 0.188
Skylark	No. birds	Poisson	Bare	7	3.88	0.300 ± .295
Meadow Pipit	No. birds	Poisson	Bare	6	1.75	0.550 ± 0.324
Chaffinch	No. birds	Poisson	Bare	4	1.74	0.511 ± 0.516

(b) Binomial models

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Red-Legged Partridge	Presence/absence	Binomial	Beet	6	1.59	0.225 ± 0.672
Pheasant	Presence/absence	Binomial	Beet	5	1.17	0.372 ± 0.867
Woodpigeon	Presence/absence	Binomial	Beet	7	1.23	0.239 ± 0.693
Skylark	Presence/absence	Binomial	Beet	11	1.03	0.537 ± 0.605
Meadow Pipit	Presence/absence	Binomial	Beet	6	1.00	0.000 ± 0.863
Pied Wagtail	Presence/absence	Binomial	Beet	6	1.21	0.563 ± 0.760
Yellowhammer	Presence/absence	Binomial	Beet	4	0.73	1.296 ± 1.241
Pheasant	Presence/absence	Binomial	Maize	5	1.05	0.000 ± 0.803
Woodpigeon	Presence/absence	Binomial	Maize	8	1.14	0.338 ± 0.584
Skylark	Presence/absence	Binomial	Maize	5	0.77	2.266 ± 1.200*
Carrion Crow	Presence/absence	Binomial	Maize	6	0.86	0.333 ± 0.821
Rook	Presence/absence	Binomial	Maize	5	0.84	0.807 ± 0.931
Blackbird	Presence/absence	Binomial	Maize	6	0.97	1.888 ± 0.827*
Yellowhammer	Presence/absence	Binomial	Maize	4	0.60	0.702 ± 1.205
Skylark	Presence/absence	Binomial	Spring rape	6	1.13	0.435 ± 0.664
Linnet	Presence/absence	Binomial	Spring rape	8	0.87	0.929 ± 0.703
Woodpigeon	Presence/absence	Binomial	Winter rape	11	1.01	0.924 ± 0.532
Skylark	Presence/absence	Binomial	Winter rape	14	1.20	0.087 ± 0.416
Meadow Pipit	Presence/absence	Binomial	Winter rape	7	0.77	0.537 ± 0.741
Pied Wagtail	Presence/absence	Binomial	Winter rape	4	0.92	0.849 ± 0.954
Carrion Crow	Presence/absence	Binomial	Winter rape	6	0.99	0.493 ± 0.709
Pheasant	Presence/absence	Binomial	Stubble	5	1.20	1.393 ± 0.793
Woodpigeon	Presence/absence	Binomial	Stubble	10	1.13	0.278 ± 0.529
Skylark	Presence/absence	Binomial	Stubble	9	0.95	1.258 ± 0.639*
Pied Wagtail	Presence/absence	Binomial	Stubble	5	1.33	0.240 ± 0.694
Carrion Crow	Presence/absence	Binomial	Stubble	6	0.89	0.334 ± 0.823
Rook	Presence/absence	Binomial	Stubble	7	0.90	1.482 ± 0.859
Blackbird	Presence/absence	Binomial	Stubble	5	0.94	2.022 ± 0.950*
Linnet	Presence/absence	Binomial	Stubble	8	0.91	0.225 ± 0.672

Species	Dependent variable	Data distribution	Crop	No. sites	Dispersion	Parameter estimate
Yellowhammer	Presence/absence	Binomial	Stubble	4	0.46	2.506 ± 1.553
Red-Legged Partridge	Presence/absence	Binomial	Bare	4	1.53	0.755 ± 0.884
Pheasant	Presence/absence	Binomial	Bare	5	0.91	0.849 ± 0.955
Woodpigeon	Presence/absence	Binomial	Bare	6	1.19	0.000 ± 0.759
Skylark	Presence/absence	Binomial	Bare	7	1.02	0.304 ± 0.783
Meadow Pipit	Presence/absence	Binomial	Bare	6	0.94	0.000 ± 0.818
Chaffinch	Presence/absence	Binomial	Bare	4	1.17	0.378 ± 0.874

CHAPTER 3   **THE EFFECTS OF GM HERBICIDE TOLERANT CROP MANAGEMENT (GMHT) ON FARMLAND BIRDS AND LARGER MAMMALS**

The Feasibility Of Using Foraging Studies To Calculate Foraging Intake Rates Of Farmland Birds

1.   INTRODUCTION

The late 20th Century saw dramatic and widespread declines in range and population density of many birds inhabiting agricultural land in the UK (Fuller *et al*. 1995; Siriwardena *et al*. 1998a) and elsewhere in western Europe (Tucker & Heath 1994). It is beyond reasonable doubt that the intensification of agriculture aimed at increasing food production has contributed to these declines (Krebs *et al*. 1999; Chamberlain *et al*. 2000; Donald *et al*. 2001) and there is now growing recognition of the need to develop management techniques to conserve and enhance bird populations on arable land.

Farm management can influence the population dynamics of birds in diverse ways. These include effects on availability of nest sites and cover. In the context of this project, farming practice also has pronounced effects on both summer and winter food abundance (Figure 1) and accessibility to that food, determined primarily by sward structure characteristics. Growing evidence suggests that changes in farming practices have had a negative impact on abundance of food resources for many birds (e.g. Donald 1998; Ewald & Aebischer 1999; Wilson *et al.* 1999).

In winter, there is considerable evidence that many species rely on foraging habitats that have declined in availability, particularly over-winter stubbles. These stubbles, including those created by set-aside, provide spilt grain and weed seeds and are important and preferred feeding habitats for many birds in winter (Wilson *et al.* 1995, 1996a; Buckingham *et al.* 1999; Mason & MacDonald 1999; Robinson & Sutherland 1999; Henderson *et al.* 2000a,b; Perkins *et al*. 2000; Gillings & Fuller in review). As stubbles have become rarer, 'artificial' sites such as game feeders and game-cover strips have become increasingly important (e.g. Stoate & Szcur 1997; Brickle 1997). Declines of many farmland birds may be linked to changes in survival, probably related to mortality outside the breeding season (Siriwardena *et al*. 1998b). Evidence that survival is important is particularly strong for the following; house sparrow *Passer domesticus* and goldfinch *Carduelis carduelis* (Siriwardena *et al.* 1999), yellowhammer *Emberiza citrinella* (Kyrkos 1997, Bradbury *et al.* 2000), song thrush *Turdus philomelos* (Thomson *et al.* 1997, 1999, Thomson & Cotton 2000), reed bunting *Emberiza schoeniclus* (Peach *et al.* 1999). That loss of winter food resources may be influencing population trends via such changes in over-winter survival is suggested by two lines of evidence. First, population trends of seed-eating birds (finches and buntings) are particularly strongly associated with differences in the extent of spring barley grown in the preceding years, this being an indirect measure of stubble availability (Chamberlain *et al.* 1998). Second, the reintroduction of stubbles in parts of Devon seems to have reversed the population decline of cirl buntings (Peach *et al.* in press).

Limitation of food availability during the breeding season may play a key role in the productivity, and hence population dynamics, of several species (e.g. grey partridge *Perdix perdix*, Potts 1986; corn bunting *Miliaria calandra*, Brickle & Harper 1999; turtle dove

Streptopelia turtur, S Browne unpublished data). While there remains the possibility that direct mortality of insects caused by insecticide is contributing to the loss of chick food resources (Brickle et al. 2000; A. Morris unpublished data), it is generally thought that the decline of the grey partridge is linked to reductions in invertebrate prey of chicks caused primarily by herbicide-induced changes in weed populations (Potts 1986). A similar mechanism may exist for other birds with similar nestling diets, although nidifugous species may be more vulnerable to this effect than nidicolous species, as the adults can search only relatively small areas for food.

As illustrated in Figure 1, changes in foraging efficiency can underpin changes in productivity or survival, which themselves may determine population trend. That is, if average food intake rate decreases, a bird could raise fewer chicks successfully, or fail to survive the winter. Data on foraging may therefore be very important in the context of understanding the effects of GMHT crop management on bird populations. First, foraging data can inform us of the mechanism underlying differences in numbers of birds between treatments. For instance, is reduced intake rate in one treatment caused by lack of food *per se* or inability to access food caused by dense sward structure? Second, and most importantly in the context of the scale of the present trials, foraging data allows us to assess impacts on birds when it might otherwise be extremely difficult to relate changes in management practice on small plots to changes in size of bird populations which operate over larger scales. Third, counts of birds can be very variable and an effect of GMHT might therefore not be noticed amongst this 'noise'. Foraging data provide a way of picking up more subtle effects which might otherwise be difficult to detect.

2.   THE POTENTIAL IMPACT OF GMHT CROPS ON FOOD FOR BIRDS

GMHT crop management may kill close to 100% of weeds in a single application, leading to dramatic reductions in weed densities compared to conventional weed control management, though the magnitude of the effect depends critically on the exact form of management (Watkinson *et al*. 2000). It has been predicted that this could lead to profound reductions in weed seed abundance, and hence food availability for wintering birds (Watkinson *et al*. 2000).

In summer, the use of herbicides may affect invertebrate prey that depend on target weeds. In recent reviews (Wilson *et al*. 1996b, 1999), the following groups were identified as being important food resources for the chicks of declining birds; Coleoptera (especially chrysomelidae leaf beetles and cuculionidae especially weevils), Orthoptera (especially acrididae grasshoppers), Diptera (especially Tipulidae crane flies and their larvae), Lepidoptera (especially caterpillars), Hymenoptera (especially symphyta sawflies and their larvae), Hemiptera (especially aphids). Most of these invertebrates are dependent on either grass or broad-leaved weeds for all or part of their life cycle. However, very few studies have investigated the potential impact of herbicides on these organisms. Moreby & Southway (1999) considered the effects of an autumn herbicide on the flora and fauna associated with field headlands of winter wheat. Arthropods were sampled in summer on headland plots sprayed at a conventional rate with an autumn herbicide and on unsprayed controls. They found significantly more chick food items (Hemiptera, Coleoptera, Lepidoptera) in untreated plots. Weed cover not only provided food for phytophagous insects used as food by birds, but also increased diversity of many groups (e.g. heteroptera) by providing suitable cover, micro-climate and refuges.

3. MEASURING INTAKE RATES OUTSIDE THE BREEDING SEASON

For birds to ingest sufficient food to survive the winter, it is assumed that they must strive to maximise their food intake rate, subject to specified constraints. One constraint for seed-eating birds is that the rate of energy acquisition is closely related to the time required to husk or handle seeds once they have been located. Optimal foraging studies provide a basis for assessment of the effects of GMHT crop management on birds, because they assume that food is limiting and that foragers behave in a way that maximizes their feeding efficiency. With knowledge of how an individual's intake rate varies with food density, the functional response (Holling 1959), it is possible to calculate the maximum number of individuals that the available food resource can support (Sutherland & Anderson 1993). Much work has been done on seed-eating birds in aviaries, but I feel that sufficient work has been done on birds in the wild to restrict this review to these more pertinent studies.

3.1 Practicalities of Observing Food Intake Rates

Observation of foraging birds has been made using binoculars or telescope, from distances varying from 10 to 35m (Smith & Metcalfe 1994; Dolman 1995; Robinson in press). For concealment, observers have watched either from a vehicle (Feare *et al.* 1974; Green 1978; Glück 1986; Smith & Metcalfe 1994) or from the cover of a hedgerow or tree (Glück 1986; Robinson in press). Recording of observations is often made on audio cassette, keeping time with a stopwatch, allowing for later transcription (Barnard 1980). Alternatively, if the subject is close enough, use of hand-held video cameras provides a useful way of measuring intake rates while making it easier to monitor other confounding variables such as inter-bird distance (A.J. Perkins, pers comm.).

The observer notes the number of items eaten per unit time by a randomly-selected focal bird (Glück 1986; Dolman 1995; Robinson in press). Typically, the bird is watched until lost from view, and then observations begin on a new, randomly-selected bird. Observation on a focal bird should perhaps also be terminated if the flock size changes (see below: Barnard 1980). Hence, to collect one datum (i.e. one feeding rate observation for one bird) typically takes from 10 to 90 seconds.

In order to estimate energy consumption (see below), it is desirable to be able to identify food items taken. In some cases, it is possible to identify the food items eaten. For example, rooks *Corvus frugilegus* hold food items in their bill tip briefly before swallowing, allowing size assessment or (if the food item is large enough) identification (Feare *et al*. 1974). However, for skylarks *Alauda arvensis*, food identification was only possible, and then for certain items only, when the focal bird was less than 20m from the observer (Green 1978). There therefore may be bias in the nature of items correctly identified.

3.2 Calculating Food Item Intake Rate

The easiest measure of food item intake rate to collect in the field is undoubtedly peck-rate (e.g. Goldman 1980) but this may be over-simplified. First, pecks can be unsuccessful (Green 1978) in obtaining a food item. Second, food items, or parts of them, can be dropped before swallowing (Greig-Smith 1985; Benkman & Pulliam 1988). Ideally, evidence of successful consumption should be observed, in the form of swallowing (Feare *et al*. 1974; Green 1978), though this may prove difficult for some species or situations (A.J. Perkins, pers. comm.).

3.2.1 Calculating functional responses

If measurements are made of food item (e.g. seed) availability, the relationship between intake rates and varying seed density can be determined (Green 1978; Barnard 1980; Dolman 1995; Robinson in press).

3.3 Turning Food Intake Rates Into Energy Intake Rates

Ultimately, the desired measure of intake rate should not simply be food item intake rate, but energy intake rate. Mean energy content of different food items can be determined by bomb calorimetery (e.g. Feare *et al*. 1974).

Estimation of energy intake requires either (i) identification of a sufficient proportion of food items that the proportion of different food item types in the diet can be estimated, or (ii) or the assumption that the bird is feeding on an approximately constant resource. Energy intake rate can then be calculated as swallow rate multiplied by calorific value per item (Feare *et al*. 1974; Glück 1985, 1986). However, this may slightly over-estimate the amount of food actually consumed, as parts of food items can be spilled (Benkman & Pulliam 1988).

3.4 Calculation of Necessary Encounter Rates or Time for Foraging

By using knowledge of daily energy expenditure (DEE, e.g. Nagy 1987), energy intake rate, and assimilation efficiency (calculated as 75% for both skylarks [Green 1978] and cardinals *Cardinalis cardinalis* and song sparrows *Melospiza melodia* [Willson & Harmeson 1973] feeding on seeds) one can determine the encounter rate with food items needed for a bird to survive. For example, Benkman & Pulliam (1988) give the following equation:

$$DEE = q \times [S / (h + \{1/\lambda\})]$$

q is the amount of time available in the day for foraging, in seconds. S is the product of mass consumed, specific energy value of the food item and assimilation efficiency of the bird feeding on that resource. h is the handling time, in seconds. λ is the necessary encounter rate.

Alternatively, knowledge of the functional response to different seed densities, can allow one to determine how long each day must be spent foraging, when confronted with different seed densities or seed types. This can enable assessment of whether different conditions provide sufficiently for different bird species to survive (Glück 1985; Robinson in press).

3.5 Other Factors Which Influence Intake Rates

When calculating intake rates in different situations, a variety of other influences on intake rate should be taken into account.

3.5.1 Habitat factors

Buried seeds are not as accessible to foraging birds as surface seeds. The depth at which seeds are unavailable varies between bird species, mainly as a result of beak size (Robinson 1997). Hence, for example, skylarks show a lower maximum intake rate on high densities of buried seed than on similarly high densities of surface seed (Robinson in press). Indeed, skylarks generally ignore fields with large but buried seed stocks (Robinson in press).

Habitat structure (e.g. taller swards) can affect a birds' ability to see other members of a flock. If a bird is in tall vegetation, and so has reduced ability to see other flock members, it will have reduced capacity to share information on predator presence and availability of resources. Both are likely to reduce intake rates, the former because each bird must spend more time being vigilant than otherwise, the latter because there is likely to be reduced information-sharing about availability of very local, high food density patches (Glück 1986).

In general, a measure of 'predation risk' (e.g. distance to cover) should be considered, as this may influence the ratio of feeding time to time spent being vigilant, and hence influence intake rate.

3.5.2 'Social' factors

Beauchamp (1998) reviews the evidence that intake rate varies with group size, with changes in intake rate being related to adjustments in vigilance behaviour and aggression towards other flock members, as well as more subtle changes in the speed of search and handling time. Dolman (1995) noted, further, that the effect of group size varies with food density. At low bird density, intake rate increases with increasing bird density (probably due to lowered vigilance per bird). Then, at higher bird densities, intake rate decreases with increasing bird density, as a consequence of interference between flock members. Age, sex and prior experience also influence intake rate (Greig-Smith 1985; Smith & Metcalfe 1994).

3.6 Success with Farmland (or Similar) Birds in Wild Situations

3.6.1 Food item intake rate

Rubenstein *et al.* (1977) were able to determine peck rates for a variety of seed-eating finches in wild situations in agricultural fields in Costa Rica, while Goldman (1980) was able to determine pecking rate (which was assumed to equal intake rate) of dark-eyed juncos (*Junco hyemalis*) in natural situations.

3.6.2 Functional responses to varying food density

Robinson (in press) was able to calculate functional responses of wild skylarks feeding on artificial food patches of different grain density, while Barnard (1980) was able to calculate functional responses for wild house sparrows *Passer domesticus* feeding in open agricultural fields.

3.6.3 Energy intake rate

Energy intake rates have been determined for wild skylarks (Green 1978), rooks (Feare *et al.* 1974), and goldfinches *Carduelis carduelis* (Glück 1985, 1986).

4. MEASURING INTAKE RATES DURING THE BREEDING SEASON

One set of optimal foraging models appropriate to breeding birds are Central Place foraging models, where the 'central place, is the nest. It is assumed that intake rate of the subject is determined by a trade-off between distance flown (and therefore time taken) to collect food and the reward in terms of energy acquisition in the prey found.

4.1 Practicalities of Nest-Finding

Nests must first be found, by observing activity of territorial birds or by systematic searching of nesting habitat (e.g. Rodenhouse & Best 1994; Stoate *et al*. 1998; Brickle *et al*. 2000; Wilson 2001; Morris *et al*. in press). This is therefore dependent on nest-finding ability of the observer and on availability of nests in the location under study. Indeed, Poulsen *et al*. (1998) employed a dog to help in nest finding.

4.2 Practicalities of Nest-Watching

Nests are watched using telescopes or binoculars, from behind blinds positioned in fences (Rodenhouse & Best 1983), from vehicles, or simply by hiding in vegetation such as hedgerows (Wilson 2001; Morris et al. in press). Observations from blinds/hides can be very close to the nest (5m, in the case of Kaspari 1991) or at a reasonable distance (e.g. $\geq$ 50-100m) from the nest, when no blind is used (Stoate *et al*. 1998; Poulsen *et al*. 1998; Wilson 2001; Morris *et al*. in press). However, it is typical that some (up to half: Kaspari 1991) nests will be in locations where it is impossible to watch foraging birds because of topography (Morris *et al*. In press). Typically, nests are watched for continuous periods of 1-2 hours (Poulsen *et al*. 1998; Stoate *et al*. 1998; Wilson 2001; Morris *et al*. in press).

4.3 Aerial Feeders

One group of species, however, is exceptional in being obligately insectivorous and in being amenable to the study of foraging rates without having to find nests. These are the aerial insectivores; hirundines and swifts. Because they are obligately insectivorous, we can guarantee that their foraging activity over a plot is related to the availability of invertebrates over that plot, which in turn is influenced by management. For other species, which have the capacity to take crop products, we cannot guarantee that their presence can be related explicitly to the effects of plot management on non-crop food availability. Ongoing studies at the EGI (Karl Evans, pers. comm.) have developed a methodology for the determination of foraging rates above specific farmland plots.

4.4 Assessment of Foraging Habitat Choice

Distance of foraging flights (i.e. the location to which a parent flies to obtain food for nestlings) can be measured by (a) placing markers at known distance from the nest, (b) the use of range-finding optics, or (c) plotting the foraging location on a map (e.g. 1: 10 000) and measuring distance from the nest to the foraging site (Stoate *et al*. 1998; Brickle *et al*. 2000; Wilson 2001), for example, using AutoCAD software and a digitising pad (Morris *et al*. in press). Habitat use can then be assessed by comparing the proportion of foraging visits to each habitat with the proportional availability of each habitat within a circle with a radius equal to the greatest length of foraging flight recorded (Stoate *et al*. 1998; Brickle *et al*. 2000; Wilson 2001; Morris *et al*. in press). Habitat use can be analysed using three methods: (a)

compositional analysis (Stoate *et al.* 1998; Brickle *et al.* 2000); (b) resampling methods (Wilson 2001); or (c) log-linear analysis (Green *et al.* 2000; Wilson 2001; Morris *et al.* in press).

4.5 Calculation of Intake Rates

A very simple indicator of intake rate can be gained by recording the visit rate to the nest. However, intake rate is determined by prey load, as well as visit rate to the nest. Hence, prey load should really be quantified. Some species facilitate this by conveniently perching next to the nest prior to delivering prey to nestlings (Kaspari 1991; R. Bradbury pers. obs.). This can enable taxonomic identification of prey, by visual scrutiny of bill contents (Kaspari 1991; pers. obs.). By categorizing prey by size, based on comparisons with bill size (Kaspari 1991), prey delivery rates can then be estimated by converting prey length into prey mass, using transformations calculated for each prey type (Kaspari 1991). However, correct taxonomic identification is not always possible (Poulsen *et al.* 1998) and can be biased towards larger prey taxa (pers. obs.) and can be complicated by delivery of multiple prey. In this case, it would be difficult to use Kaspari's method consistently. One alternative would be simply to estimate the total size of load, irrespective of prey identity (Poulsen *et al.* 1998). However, even if this were possible, it would still not account for variation in nutritional value (which is how intake rate should ultimately be measured) between prey types. Finally, account should be taken of the number of nestlings, so that intake rate per nestling can be determined (Poulsen *et al.* 1998).

4.6 Considerations When Analyzing Intake Rates

Intake rates vary during the course of the day (Poulsen *et al.* 1998) and vary with nestling age and weather conditions (Kaspari 1991; Poulsen *et al.* 1998).

4.7 Results for Farmland Birds

Foraging rates were established in the following studies: for skylark, Poulsen *et al.* (1988) noted 5.75 visits per hour in the morning and 6.45 visits per hour in the afternoon/evening; for yellowhammer, Stoate *et al.* (1998) recorded between five and fifteen foraging flights per observation period (1.5-2 hours). However, in neither these or other UK studies were prey identified at the nest, so energy intake rates were not determined.

4.8 Constraints

In farmland bird studies, it has proven eminently tractable to measure habitat selection (e.g. Stoate *et al.* 1998; Brickle *et al.* 2000; Wilson 2001; Morris *et al.* in press) and food delivery rates to the nest (e.g. Poulsen *et al.* 1988; Stoate *et al.* 1998). It would be possible to measure relative use of adjacent GM and non-GM plots, with respect to their relative distance to focal nests. However, there are several limitations with regard to measuring intake rate with respect to specific habitat patches, such as a particular plot under GM management.

(i)   Nest-finding can be very time-consuming and topography will preclude the successful watching of some nests.
(ii)   To properly estimate energy intake rates, food items must be identified or, at least, food item load be assessed. Either can prove difficult.

(iii)   Some species switch nestling diet at particular points in the breeding season, from invertebrates and weed seeds, to a diet dominated by crop products. This includes yellowhammer (switches from invertebrates to unripe cereal grain; Kyrkos 1997) and linnet (switches from weed seeds to oilseed rape seed; Moorcroft *et al.* 1997). Other finches, such as bullfinch, also seem to switch nestling diet to rape at this stage of the summer (F. Proffitt, pers. comm.). For such species, the ability to determine effects of plot management on plot usage (as a function of prey availability) will be clouded by the availability of crop product which can be taken by the birds, which is not expected to vary between GM and non-GM plots. Hence, data collection pertinent to the assessment of GMHT effects would have to be restricted to the period prior to availability of crop product.

(iv)   Most importantly, foraging rates will be determined by the nature of all the habitats around the nest. Both adjacent GM and non-GM plots will therefore influence observed foraging rates, preventing their individual effects on foraging rate from being disentangled.

5. CONCLUSIONS

The assessment of the effect of GMHT crop management on foraging intake rates of breeding birds seems problematic, though it may be possible to investigate selection of GM plots, relative to non-GM plots, particularly by assessment of foraging activity over GM and non-GM plots by aerial feeders. The collection of foraging rate data from winter birds seems more tractable and may detect subtle effects of GM treatment which may not be manifest in the short-term in numbers of birds on GM and non-GM plots. This would be important, as differences in foraging rates on different plots ultimately underpin long-term differences in numbers. Collection of data would require intensive fieldwork at intervals throughout the winter, to assess the effects of depletion of seeds during the course of the winter, and should be repeated in several winters to reduce the impact of annual variation in, for example, weather effects. However, it is likely that the data so collected would provide the most appropriate means, given the short length of the current trial, for assessment of effects which might not be obviously manifest in terms of numbers of birds utilizing the plots.
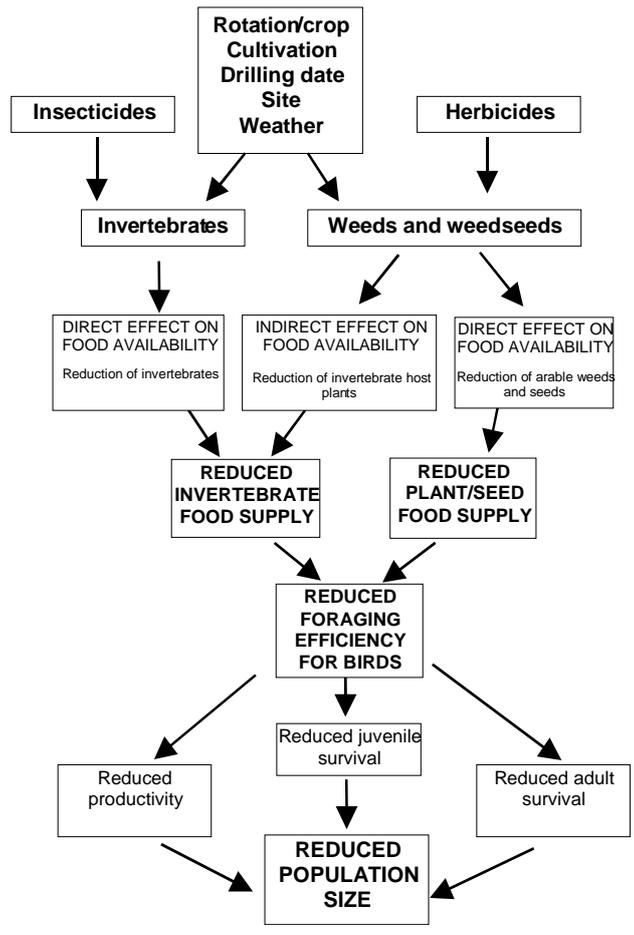
Figure 1   Food-linked factors affecting farmland bird populations.

CHAPTER 4   **A FEASIBILITY STUDY ON THE COLLECTION OF FORAGING AND INTAKE RATE DATA ON FSE TRIALS IN WINTER**

1.   INTRODUCTION

Together with the densities of individuals a given field attracts or is able to support, a key measure of the ecological value of a field to birds is the food intake rate they achieve while feeding on it. In the context of the GMHT FSE trials, it is of interest whether birds achieve different intake rates in crops under GMHT or conventional management.

The most straightforward approach to estimating intake rates for terrestrial birds is observational. Unfortunately, this means that it almost impossible to collect data on birds feeding in dense vegetation such as a growing crop. However, crop habitats are much more amenable to observation after harvesting and there is growing scientific evidence as to the importance of both stubble fields in particular and over-winter survival in general for many birds. This suggests that winter field habitats may be the most appropriate biological context in which to investigate intake rates of birds in the FSE trials (Bradbury 2002). In this report, preliminary results of a study into the feasibility of measuring such intake rates are presented.

2.   METHODS

The feasibility of collecting intake rate data from the GMHT FSE trial sites in winter was investigated from two directions, asking: 1) for which species could sufficient individuals be found regularly to allow data to be collected efficiently, and 2) whether intake rates could actually be measured adequately in the field.

To investigate the numbers of birds found at each site, all survey field maps completed up to 1 February 2001 for 41 sites (22 beet, 9 maize and 10 spring rape) were reviewed and the numbers of all species recorded in the target fields themselves calculated. Birds in field boundaries were not considered, both because of the difficulty of observing birds within boundary vegetation and because these birds' foraging in the boundary will be influenced relatively little by the previous spring's crop management. Winter rape plots were not considered and counts were not separated by treatment (at this stage). Crop-specific mean counts per survey visit and probabilities of finding each species on a given visit were then calculated.

To investigate whether intake rates could be measured in the field by direct observation, survey results from FSE sites in East Anglia were examined to reveal whether reliable concentrations of birds could be found so that detailed observations of foraging behaviour could be planned. Such concentrations were not found, so an alternative beet stubble field was selected (a field site from the BTO's stubbles project near Weeting, Suffolk within c. 20 km of a number of FSE sites) on which good numbers of several species could be found reliably. At this field, and, opportunistically, on regular survey visits to two beet FSE fields, intake rates were measured for all observable species feeding on the open field concerned. Three protocols were considered: 1) observing individuals to record the time taken to make fixed numbers of pecks or to obtain a fixed number of food items, 2) observing individuals for a fixed period of 1 minute and counting pecks and food "captures", and 3) observing individuals for as long as possible and counting pecks and food "captures". Preliminary observations led to the choice of the third method, in which pecks and food item "captures" were counted simultaneously using two tally counters while birds were observed through a telescope.

3.   RESULTS

3.1   Species Occurrence on FSE Fields

Crop-specific species mean counts and probabilities of finding each species are shown in Table 1. It was rare for a species to be found on a crop type commonly and in sufficiently large numbers potentially to allow reasonably large intake rate sample sizes to be collected. The most promising crop/species combination involved Linnet on rape fields: the species was found on 41% of visits to the eight sites where it was recorded at least once and with a mean flock size of 23 (Table 1c). Other combinations with the potential to provide good quality data were Skylark on beet and Wood Pigeon on beet: these species were recorded at ten and eleven sites, respectively, on 51 and 33% of visits and with flock sizes of four and thirteen (Table 1a). However, even these species were found on a maximum of only 4% of all visits to sites with the appropriate crops, so it would be impractical to plan intake rate data collection without foreknowledge of the species using a given site. Note also that the results presented probably overestimate, for practical purposes, the numbers of some species (e.g. Wren, Dunnock) using beet crops because these species will only use the crop before it is harvested and therefore will not be observable.

3.2   Intake Rate Estimates

Observations were conducted at the Weeting beet stubble field on 19 January 2001 and (after several other unsuccessful attempts) at site B3 on 24 January 2001. In a total of 4 hours of observation, the data presented in the Table 2 were collected. It is notable that the average times that individuals were observable tended to be low, especially for the smaller species. Note also that the range of species is limited and that the data collection periods yielded one data point per 8.6 minutes (the observations lasting 65 seconds, on average). Notwithstanding the fact that these results represent data from the best-case scenario, i.e. large numbers of birds known to be present and no restrictions on the species that are of interest, the standard errors for the one species with a reasonable sample size (Greenfinch) are small enough that differences between crop management types might well be detectable with samples of this order if they existed.

The following observations are relevant to the feasibility of collecting data of this kind on a larger scale: 1) a closer approach is necessary for smaller birds and such species tend to be more flighty and visible for shorter periods; 2) visibility can be a problem with respect to topography, any vegetation still in the field and furrows in the soil, so that sites may be unsuitable for observation even if they hold large numbers of birds; 3) observer disturbance can be a problem: this is lessened by the use of a car as a hide (and a purpose-built hide would have the same effect), but visibility is often then compromised; 4) sites with more birds attract predators such as Sparrowhawk which cause disturbance and disrupt observation; 5) conducting other fieldwork such as the baseline winter FSE bird survey disturbs feeding birds so foraging observations should be carried out independently (or given a higher priority) to maximize the numbers of species and individuals observable.

4.   CONCLUSIONS

It would be feasible to collect intake rate data from FSE trial sites in winter as recommended by Bradbury (2002), after crop harvest, provided that data collection is opportunistic and conducted by fieldworkers prior to and as a priority over regular survey work or that it is conducted in carefully timed, dedicated site visits. In the latter case, visits should be timed to follow harvest within a few days to maximize the data output per unit observer effort: random or regularly spaced visits are likely to be extremely inefficient. Species selection would best be opportunistic, with subsequent analyses focusing on the commonest species or on ecologically coherent species groups. Based on this pilot study, these are likely to include important granivorous farmland birds such as Skylark, Yellowhammer and possibly also Linnet. On balance, the use of hides is unlikely to be practicable, but observers should first try to collect data from a vehicle to minimize disturbance. Subsequently, or if topography and access do not favour car-based observation of both halves of the trial field, observations should be made on foot (from cover, if possible).

Table 1   Mean counts per survey visit and finding probabilities for species found on FSE crops (present on a minimum of two sites). Birds found in the cropped area itself and in the field boundary are separated. Finding probabilities are shown based only on sites where a given species was found on at least one visit and based on all sites.

(a) Sugar beet

Species	No. sites found at	Mean visit count	Mean Finding Probability at a crop site	
			if known to occur at site	across all visits to crop
Blackbird	3	0.56	0.333	0.004
Black-Headed Gull	2	17.17	0.500	0.020
Chaffinch	3	1.42	0.389	0.008
Dunnock	7	0.71	0.381	0.009
Goldfinch	2	0.83	0.333	0.007
Greenfinch	2	22.08	0.542	0.018
Linnet	5	3.78	0.383	0.011
Meadow Pipit	10	1.44	0.450	0.020
Grey Partridge	4	2.33	0.458	0.013
Pheasant	6	0.47	0.319	0.008
Redwing	2	0.83	0.333	0.007
Red-Legged Partridge	5	3.72	0.483	0.015
Rook	2	3.50	0.250	0.007
Skylark	10	3.86	0.508	0.019
Starling	3	0.75	0.278	0.013
Song thrush	2	0.29	0.292	0.007
Woodpigeon	11	14.31	0.326	0.011
Wren	4	0.27	0.271	0.005
Yellowhammer	7	1.70	0.345	0.012

(b) Maize

Species	No. sites found at	Mean visit count	Mean Finding Probability at a crop site	
			if known to occur at site	across all visits to crop
Blackbird	5	1.05	0.450	0.036
Carrion Crow	3	0.50	0.333	0.027
Chaffinch	3	1.67	0.583	0.020
Dunnock	3	4.42	0.333	0.018
Jackdaw	3	5.75	0.333	0.036
Linnet	2	0.75	0.250	0.024
Meadow Pipit	2	2.38	0.625	0.036
Grey Partridge	2	5.63	0.625	0.089
Pheasant	4	0.56	0.375	0.036
Pied Wagtail	3	1.33	0.583	0.071
Robin	4	0.44	0.375	0.022
Red-Legged partridge	2	2.63	0.500	0.071
Rook	4	16.44	0.375	0.036
Skylark	3	1.25	0.500	0.060
Snipe	2	0.88	0.625	0.054
Woodpigeon	5	23.40	0.450	0.036
Wren	4	0.31	0.313	0.024
Yellowhammer	4	0.56	0.250	0.036

(c) Oilseed rape

Species	No. sites found at	Mean visit count	Mean Finding Probability at a crop site	
			if known to occur at site	across all visits to crop
Black-Headed Gull	2	0.79	0.292	0.030
Carrion Crow	3	0.83	0.417	0.024
Goldfinch	2	14.50	0.625	0.030
Linnet	8	23.09	0.406	0.042
Meadow Pipit	2	2.25	0.375	0.045
Grey Partridge	2	2.88	0.250	0.020
Pied Wagtail	2	0.25	0.250	0.030
Skylark	6	3.29	0.583	0.066
Woodpigeon	2	13.13	0.500	0.015

Table 2   Observation times and foraging rates of birds observed on sugar beet stubbles in winter in a total of 4 hours observation time.

Species	N	Mean time observed, s	Mean peck rate	SE	Mean food capture rate	SE
Fieldfare	2	25.0	5.000	1.000	1.000	1.000
Greenfinch	17	29.5	16.556	1.797	9.572	1.844
Linnet	2	9.0	27.000	3.000	6.000	6.000
Mistle Thrush	6	166.7	5.818	2.362	2.099	0.925
Red-Legged Partridge	2	95	7.841	6.341	6.273	6.273
Wood Pigeon	1	200	18.600	-	5.700	-

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