

# **FARM SCALE EVALUATIONS OF GM CROPS:**

## **EFFECTS OF THE MANAGEMENT OF FIELD SCALE RELEASES OF GENETICALLY-MODIFIED HERBICIDE- TOLERANT CROPS ON THE ABUNDANCE AND DIVERSITY OF FARMLAND WILDLIFE**

### **Interim Report**

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## EXECUTIVE SUMMARY

1. This is the fourth Interim Report of the Farm Scale Evaluations of Genetically-Modified Herbicide Tolerant (GMHT) crops. The principal research objectives for the period of this report were as follows:
  - Completion of data collection from the spring 2000 sites
  - Early rounds of data collection from the autumn 2000 (winter rape) sites
  - Re-assessment of field protocols, and submission of any recommended changes to the Scientific Steering Committee (required by February 2001 to be in time for the next field season)
  - Continued progress in data entry, validation, management and analysis procedures
2. There remains some crop management data still to be collected from the summer 2000 sites, and there remains a backlog of invertebrate samples to be sorted. This backlog should be cleared by the end of March 2001. Of the 25 planned winter rape sites, one could not be sown because of flooding, and another was withdrawn because of an error in site layout. The programme of biodiversity assessments is proceeding smoothly. Data entry protocols are working well, but the rate of data punching is currently too slow, and will need to be improved.
3. Revised estimates of power are presented, using field data collected from beet crops in 2000. For a wide range of species groups, the statistical power of the experiment, with 60 sites, exceeds 80 %. This power may be increased with the use of covariates.
4. The protocols have been revised in the light of experience and data from the summer 2000 sites. The main changes are to the timing and frequency of site visits, and also to the sampling intensity per visit. In addition, worm casts are now being counted. This is to follow up observations by some farmers that these differed in numbers between treatments last summer.
5. Site selection for spring 2001 is progressing well. To date, SCIMAC has offered 50 spring rape sites, 34 beet sites and 26 maize sites. More sites are expected, especially for maize, which is planted after the other crops. Final site selection awaits the analysis of questionnaire returns from farmers. We expect to meet our target numbers of sites.
6. Data from summer 2000 beet crops were analysed in order to detect any differences in biodiversity responses between sugar and fodder beet crops. No treatment x variety interactions were detected. Therefore, we recommend that these crops are considered together in future for the purposes of this experiment. However, both varieties should still be included in the selection of sample sites, in order to cover the range of farming systems, locations and geography that is encompassed by beet farming in Great Britain.

- 7 Work is progressing on methods of interpreting data arising from the study. We have agreed that, in order to understand the implications of our results for biodiversity at the national scale, we need to arrive at a means of running **scenarios** to explain the role of **disturbance** - mediated primarily by **farmer behaviour** - in the balance of **functional groups** in important **trophic layers** at a range of **scales** including **field margins**.

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## 1 INTRODUCTION

This is the fourth Interim Report of the Farm Scale Evaluations of Genetically-Modified Herbicide Tolerant (GMHT) crops. The first two reports, in October 1999 and March 2000, covered the period in which the project was very much in its development phase, and data were being collected only to develop and refine the methodology.

The previous report noted that the research objectives for the period October 2000 – March 2001 were as follows:

- Completion of data collection from the spring 2000 sites
- Early rounds of data collection from the autumn 2000 (winter rape) sites
- Re-assessment of field protocols, and submission of any recommended changes to the Scientific Steering Committee (required by February 2001 to be in time for the next field season)
- Continued progress in data entry, validation, management and analysis procedures
- Submission of manuscripts to journals on overall project approach, experimental design and protocols
- Provision of feedback to farmers who have taken part in the project so far

In addition, site selection for the spring-sown crops in 2001 is taking place within this period.

This report covers the period October 2000 – January 2001, and so not every objective noted above has been completed. The priority for this period has been continued data collection, the re-assessment of field protocols and continued progress in data entry and validation.

## 2 FIELD ACTIVITY, OCTOBER 2000 – JANUARY 2001

### 2.1 Fieldwork on pilot study sites

Fieldwork on the pilot sites was completed during the previous reporting period.

### 2.2 Monitoring biodiversity

A small number of field assessments were undertaken on the spring-sown sites in the period of the report, i.e.

<i>Beet</i>	1 gastropod verge assessment
<i>Spring rape</i>	1 vegetation margin assessment 1 weed seed rain assessment

These spring-sown sites will be revisited in summer 2001 for weed assessments.

Twenty five sites were selected for the winter oil seed rape programme for 2000 – 01. Of these, 24 were sown; the remaining site was lost because of flooding. One of the other sites was withdrawn shortly after sowing because of an irretrievable error in the site layout. The field programme on the remaining 23 winter oil seed rape sites is now well advanced (Table 2.1). Crop establishment has been poor on one of the sites, which therefore may be withdrawn – this decision will be made later in the winter.

**Table 2.1** *Progress on field protocols of the 23 winter oil seed rape sites, reported up to 15 Jan 2001.*

<i>Protocol</i>	<i>No. sites</i>
Splitting	23
Layout & context	23
Margin attributes	23
Soil seedbank	23
Gastropod verges1	22
Gastropod crop 1	22
Seedling 1	22
Crop pest 1	22
Vortis 1	21
Carabids 1	19

### **2.3 Progress in data collation and validation**

The project still has a large backlog of unsorted invertebrate samples from summer 2000. This is due to be cleared by the end of March, meanwhile priority has been given to batches of samples used to generate statistical analyses that underpin re-assessments of protocols. There remains some crop management data still to be collected summer 2000 sites.

The protocols for data entry and validation are working well, but further development is needed. However, at the current rate, data punching for the 1999 field season will not be completed until well into the summer 2001. This rate needs to be improved as part of the move to a more rapid turnaround of information from the field to the validated database; we are looking at providing more resources to support data entry.

### **2.4 Damage to crops**

The autumn was characterised by extremely wet weather, yet there appears to have been little obvious damage to the field sites. There has been one minor incidence of deliberate damage during the period of this report, to a winter oil seed rape site.

### 3 REVISED POWER CALCULATIONS BASED ON 2000 DATA

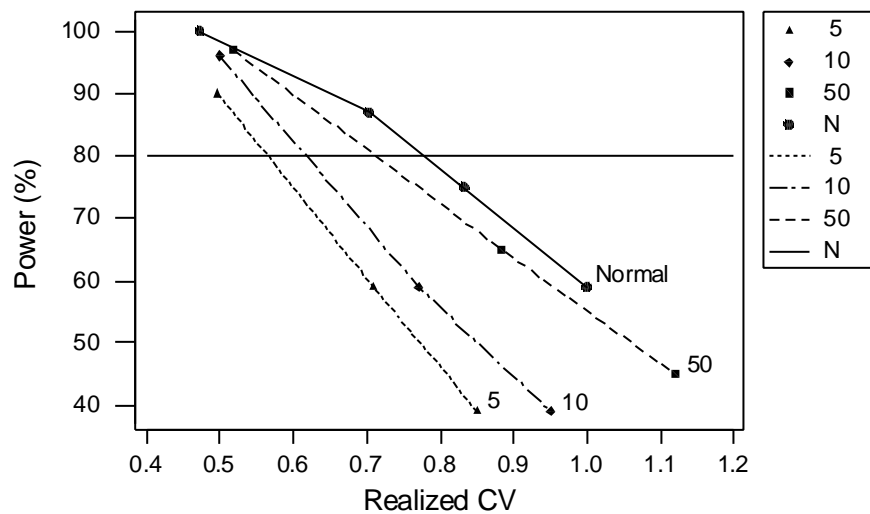
The Scientific Steering Committee Meeting (November 2000) recommended revision of the power calculations using data collected in 2000. In particular, for a range of groups, the requirement was to estimate (a) the power for detecting a 1.5-fold difference (at the 5% level) for the proposed design with 60 sites, and (b) the number of sites required to achieve a power of 80% for detecting a 1.5-fold difference. This section reports the results of the analysis.

#### 3.1 Method

The simulation power study showed that for count data the power depends on the underlying model, and in particular on the mean and coefficient of variation (CV) of the count. Figure 3.1 illustrates this for the model in which the variance of the count is proportional to the square of the mean (i.e. constant CV). The power decreases with increasing CV and decreasing mean count. Similar patterns are shown by the other models.

An important point to note is that the power exceeds 80% for CVs up to about 70%, provided that the mean is not too small. So, although the early discussions of power have tended to emphasise a CV of 50%, relatively high power can be achieved in many cases for CVs up to about 70%.

**Figure 3.1** Power for detecting an  $R = 1.5$ -fold difference with  $n = 60$  sites using the  $d$ -statistic applied to count data from the negative binomial model with variance proportional to the square of the mean. Power shown in relation to the average realized CV (500 simulations) for different levels of mean count. Results of lognormal model shown for comparison.



To estimate power from the data we have developed empirical models to predict power from the observed CV and the mean count. For the case shown in Fig. 3.1 the predictive model is given by

$$\text{logit (Power)} = -3.287 + 1.625H - 18.62/m$$

where  $\text{logit}(p) = \log[p/(1 - p)]$ ,  $m$  is mean count and  $H$  is a quantity (a so-called non-centrality parameter) which depends on the CV, the sample size ( $n$ ) and the magnitude of the difference to be detected ( $R$ ), and given by

$$H = \log R / \sqrt{(2CV^2/n)}$$

Predicted values have a mean absolute error of less than 2 percentage points. Corresponding relationships have been calculated for the other simulation models with variance proportional to mean and to mean raised to the power 1.5. The choice of relationship to apply in a particular case has been guided by examination of residuals from the fitted model with variance proportional to mean (Carroll & Ruppert, 1988).

For biomass data, power has been estimated using the lognormal model. In the analysis biomass was log transformed after adding half of the lowest recorded value, i.e. by using  $\log(\text{biomass} + 0.005)$ .

## 3.2 Results

In what follows, power refers to the power for detecting a 1.5-fold difference (at the 5% level) for a design with  $n = 60$  sites, on the basis of sampling intensity as used in the revised protocols (Section 4).

### 3.2.1 Weed seed bank density

For each crop the major groups analysed were total density, densities of dicots and total monocots less *Poa annua*. In all cases save one the estimated power exceeds 80%. The single exception is *Poa annua* in spring oilseed rape where the power falls to 63%.

### 3.2.2 Seedling 1 density

Seedling density for the first sampling occasion on the conventional crop was affected by applications of pre- and post-emergence herbicide which inflated the values of the CVs in the basic analysis. Estimates of the CVs were therefore obtained by including pre- and post-emergence herbicide applications as covariates, to obtain more realistic values for comparison of GM and non-GM crops. In some cases the reduction in CV after allowing for pre- and post-emergence herbicide effects was substantial. The estimated power for detecting a difference in densities of monocotyledonous and dicotyledonous species exceeds 80 % for each of the three crops, when the effects of pre-emergence were accounted for. The only exception was for dicotyledonous species in maize, where it falls to 63 %.

### 3.2.3 *Weed biomass*

Estimated CVs for the weed biomass are large with low power for detecting a 1.5-fold difference. However these large values of the CVs imply rather unrealistic levels of random variation between the two field halves. It seems likely that some of this variation is reflecting a site by treatment interaction effect.

### 3.2.4 *Vortis counts: beet*

The analysis of the Vortis counts uses the groups Collembola, Diptera, Coleoptera, Parasitica, Auchenorhyncha and Araneae, and the functional groups Detritivore (i.e. Collembola), Phytophagous, Predator and Parasitoid.

In most cases the estimated power exceeds 80%. However, counts of Collembola in the field verge show high variability (CV = 98%) and lower power (69%). For these counts the estimated sampling error CV = 50%, so increasing the number of transects 3 to say 6 still leaves an overall CV = 91%. Further examination of the data is needed to try to account for the large amount of variation.

### 3.2.5 *Pitfall trap verge counts*

The analysis uses the species *Harpalus rufipes*, *Calathus fuscipes*, *Pterostichus madidas* and *Pterostichus melanarius*, and total carabids. Power is estimated for a scheme with 4 traps and the question of whether there is a need to use 8 traps is addressed.

Total carabids have high power (99%), and for individual species power exceeds 80% except for *Harpalus rufipes* which is only slightly lower (73%). There is no evidence to support an increase in the number of traps from 4 to 8 (but see 4.2.6).

## 3.3 **Conclusions**

The main points from the analysis are as follows.

- (a) For a wide range of vegetation and invertebrate groups the statistical power for detecting a 1.5-fold difference between treatments exceeds 80%
- (b) The seedling 1 density data demonstrate the effectiveness of including covariates in the analysis to reduce variability and increase power.

## 4 PROTOCOL DEVELOPMENT

### 4.1 Introduction

The previous report introduced the re-assessment of field protocols that has been taking place as part of the continuing process of project management. The re-assessment involves consideration of

- *Changes to sample frequency*, i.e. increasing or reducing the number of times a particular protocol is carried out
- *Changes to sampling intensity per visit*, usually by changing the number of observations / sample points taken at any one time.
- *Changes to sample identification protocols*
- *Changes to methods* These are considered only if it is felt that the present protocol has simply not delivered the quality of data required for the project.
- *Practical issues*, such as optimum ways of planning surveys etc.

The major concerns were to use data from last season to reconsider sampling intensity, to take into account experience from last season, and to increase the efficiency of the fieldwork.

The most substantial changes to the field protocols involved changes to the timing and frequency of visits. This was to increase the efficiency of the field surveys, whilst drawing upon last season's experience to ensure that key phases of the development of the crop and its associated biodiversity remain well monitored. Secondly, sampling intensity per visit has been revised for some protocols in the light of analyses of last season's data. Changes in methodology were minor. There is an important addition to the vegetation protocols, in that worm casts will be counted next year. Little or no change in protocols is expected from March 2001 onwards.

### 4.2 Revisions to protocols

#### 4.2.1 *Crop management data*

The crop management data forms are being revised to include information on weed growth stage as part of the decision-making process, and also to make it easier for the farmer to provide information to the Consortium and SCIMAC, without repetition.

#### 4.2.2 *Within-crop vegetation and worm casts*

There are several additions to the protocol:

- Addition of late winter sampling to measure over-winter survival of WOSR, before spring herbicides are applied
- Permit biomass sampling of 50 cm square in the small number of very weedy cases where 1 m square produces more weeds than can conveniently be taken back for sorting
- Addition of counting worm casts, as prompted by farmer observations

- Addition of size categories for seedling counts (0-3 true leaves, 4 or more leaves and at biomass sampling distinguish flowering or fruiting plants from others). This information will help interpret crop management, as well as the dynamics of the weed community.

#### 4.2.3 *Seed rain*

The trap design has been refined, and the traps will be located at the corners of 1x1m quadrat. It is proposed to change the frequency of trap emptying from every 2 weeks to every 4 weeks.

#### 4.2.4 *Edge vegetation and flowers*

The timing of sampling now coincides fully with that for bee and butterfly monitoring. The current protocol requires that seeds in the edge vegetation are recorded; this may be redundant, if the presence of flowers equates with the presence of seeds. Further analyses of the 2000 data are required to test this point.

#### 4.2.5 *Gastropods*

The concern was that low numbers of slugs were caught last summer within the crops. Therefore, it is proposed to increase trap intensity from 1 to 4 at each sampling point, and to use “layers mash” as a slug arrestant. Sampling timing is, for spring-sown crops, one visit in Spring and Autumn, and for winter oil seed rape, one visit in Autumn (year  $n$ ), Spring ( $n+1$ ) and Autumn ( $n+1$ ). Last year’s spring sown crops were visited four times.

#### 4.2.6 *Soil surface-dwelling invertebrates – pitfall sampling*

It is proposed that there should be three sampling occasions per year. One species of carabid larvae will now be counted as well as just totals. Wing morphs of three species of carabids will now be counted in addition to the species level identification of adults. Rather than only counting total spider numbers, this group will now be split into six taxonomic groups. Analyses to date suggest that the additional traps at the crop edge requested by the SSC are not required to obtain adequate CVs (Section 3.2.5), although further analyses are being undertaken to identify any treatment x trap location effects.

#### 4.2.7 *Crop pests*

The timing of the crop pest surveys has changed to two visits per year. The field protocol remains unchanged from that used in August 2000, i.e. actual numbers of pests/predators counted instead of presence/absence, and number of plants reduced from 90 to 45 per half field.

#### 4.2.8 *Invertebrates on vegetation – Vortis sampling*

It is proposed to reduce the sampling occasions three to two, per site per year. It is also proposed to reduce the number of transects sampled per occasion from nine to three. The biodiversity indicators are now identified in terms of both taxonomic and

functional groups. The taxonomic groups are: Collembola, Carabidae, Heteroptera, Homoptera, Aphidoidea, Auchenorrhynca, Coccinellidae, Curculionidae, Lepidoptera larvae, Symphyta larvae, Parasitica, Diptera, Neuroptera, Orthoptera, Spiders. The functional groups are: Herbivores, Polyphagous predators, Parasitoids, Detritivores.

#### *4.2.9 Bees and butterflies*

It is proposed to reduce the number of visits per site from six to four visits (1 per month) in beet and Winter rape and to three visits (1 per month) in Spring rape and maize. The edge vegetation protocol will now be performed on the same day as each bee/butterfly transect. If rape or maize is in flower, there is no longer a need to count flowers, but a crop assessment must be performed.

### **4.3 Revised field work timetables**

The changes to the timing and frequency of site visits are summarised in Figs 4.1 and 4.2.

### **4.4 Health and safety**

There has been no safety incident during the reporting period.

### **4.5 Training**

The next training meeting will be in early March; this will cover all main field protocols for the summer field season.





## **5 SITE SELECTION FOR SPRING-SOWN CROPS, 2001**

### **5.1 Progress in site selection for spring 2001**

The minutes from the SSC meeting of 1 November 2000 request that we aim at 32 sites for each of the spring-sown crops for the year 2001. There is also a need to correct geographic imbalances from the first year site selection, e.g. the scarcity of sites in south of England and Wales.

At the time of reporting, the provision of sites by SCIMAC is going well. We have been offered 50 sites for spring rape, 34 for beet and 26 for maize. Maize site selection lags behind the other crops, as it is the last to be planted and more additional offers are expected for this crop than for the others in the coming weeks.

The sites offered to date extend the range of possible sites into Wales, and increase the possible number of sites in southern England and in Scotland. A maize site has also been offered in Northern Ireland.

More details will be tabled to the SSC. The final site selection will be made once questionnaires have been returned by farmers. We currently expect to be able to meet our target numbers of sites for the coming year.

### **5.2 Sugar and fodder beet**

There are two types of beet crop, sugar and fodder. While they differ in agronomy, it is not clear whether they should be treated as two separate crops for the purposes of this project, and this decision has been deferred until more information became available. We now present such information. The difference between the biodiversity associated with two crop types themselves is represented by a single degree of freedom contrast between the sites and may be estimated if required, but contains no information concerning the treatments of GM and non-GM crops. While it might be interesting to investigate whether fodder beet sites have greater levels of biodiversity than sugar beet, this is not essential information for the question of whether fodder and sugar should be considered as one crop for the purposes of analysis in the FSE.

Instead, the objective of this analysis is to compare the effect of the two levels of the main treatment factor, GM versus conventional, across the two levels of the factor defining crop type within beet. This is equivalent to looking at the *interaction* between treatment and crop type, which is also a single degree of freedom contrast. A skeleton analysis of variance is provided in Table 5.1; there are ample degrees of freedom for testing. In this section, we report analyses using data collected in 2000 to help come to a decision as to whether the two varieties should be treated as separate crops.

**Table 5.1.** *Skeleton analysis of variance for the 24 beet farms for year 2000, at which 15 were sugar and 9 were fodder crops. The blocking factor representing crop type is denoted as C, with two levels. The main effects measured by blocking factors are estimated in the farms stratum. The main treatment factor, comparing GMHT versus conventional, is represented by T. The main effect of T and the CxT interaction are estimated in the half-field units stratum. All F-tests are based on 22 residual degrees of freedom.*

<i>Source of variation</i>	<i>df</i>
<i>Farms stratum</i>	
C	1
Sites within crop types (14+8=)	22
Total	23
<i>Half-field units stratum</i>	
Total farms (blocks, from above)	23
main effect of T	1
T × C interaction	1
Residual	22
Total	47

### 5.2.1 *Seedling counts*

Initially the analysis are illustrated with data from the first seedling counts from year 2000. All analyses illustrated assume the lognormal model, that diagnostic tests have found to be suitable for vegetation data. For the first seedling counts, the application of pre- and post-emergence herbicide to some of the conventional half-fields had already been shown to have a strong effect on estimation of the main effect for treatment. A further analysis, restricted now to those eight sites that received no pre- or immediate post-emergence herbicide showed that there was no sign of any difference between sugar and fodder beet sites, or, more importantly, of any interaction between crop type and treatment.

In summary, the first seedling counts show no evidence either of a difference between sugar and fodder beet sites, or, more importantly, of any interaction between crop type and treatment.

### 5.2.2 *Weed biomass*

Results confirm that, again, there is no indication either of a consistent difference between sugar and fodder beet sites, or of any interaction between crop type and treatment.

### 5.2.3 *Weed seed bank*

The next data concern weed seed abundance from the seedbank protocol, which have a different structure to the variates considered above. Here, samples were taken after splitting the field into halves, but before sowing, so no treatment had yet been applied. Hence there was no reason to expect any difference between the treatments. *Looking at the interaction between crop type and treatment is therefore meaningless.* Abundance was generally lower for farms that had grown only sugar beet in the past; there was little difference between farms that had grown both sugar and fodder and those that had only grown fodder beet. Abundance was lowest on farms that grew only sugar beet for both monocots, dicots and, indeed, for every individual species examined.

Hence, in contrast to the results described above, that showed that the measured vegetation above ground at different times in the season did not differ between sugar and fodder, this was not the case for the seedbank. The potential weed abundance in the absence of any treatment and ignoring effects of competition, was greater for fodder beet fields.

### 5.2.4 *Invertebrates*

Results to date (for carabids and the vortis samples of beet crops in summer) showed only one test of the interaction was significant at the 5% level, not an unusual occurrence when ten independent tests were performed.

### 5.2.5 *Conclusion and recommendation*

In summary, for neither vegetation nor invertebrates was there any detectable effect of a difference in the effect of the two levels of the main treatment factor, GM versus conventional, across the two levels of the factor defining crop type within beet.

We therefore recommend that that fodder and sugar should be considered as one crop for the purposes of site selection in the FSE.

However, both varieties should still be included in the selection of sample sites, in order to cover the range of farming systems, locations and geography that is encompassed by beet farming in Great Britain.

## **6 PUBLICATIONS AND PUBLIC RELATIONS**

### **6.1 Publications during the period October 2000 – January 2001**

No new publications appeared during the reporting period.

The methodology papers are due to be ready to be submitted to a refereed journal by the end of March 2001.

### **6.2 Policy issues**

The project co-ordinator has been invited to give evidence to the AEBC in February 2001.

## **7 THE FUTURE PROGRAMME**

### **7.1 Progress towards completion**

In general terms, the project is on timetable, as long as the process of sample sorting and data entry can be speeded up.

### **7.2 Objectives for the period February 2001 – September 2001**

The following major tasks are scheduled for the next period of the report (NB the timetable overlaps with the previous report, and so some tasks also overlap)

- Resurvey spring 2000 sites
- Complete field work on winter 2000 sites
- Undertake site selection and field survey on the spring 2001 sites
- Completion of data entry and validation for spring 2000 sites
- Submission of manuscripts to journals on overall project approach, experimental design and protocols
- Provision of feedback to farmers that have taken part in the project so far
- Continued development of data analysis procedures
- Planning for publication of the final report

### **7.3 Next steps for data analysis**

The data interpretation for the project is complicated because there are a large number of biodiversity variables that can be subjected to tests of null hypotheses. It is therefore important to be able to integrate these results together, in some form of model. This could take many forms, from detailed population dynamics models of key organisms, to less formal models, such as decision trees.

The Consortium held a workshop in December to consider issues and techniques involved in modelling and interpreting the data. We arrived at a mission for this part of the work:

*We need to arrive at a means of running scenarios to explain the role of disturbance - mediated primarily by farmer behaviour - in the balance of functional groups in important trophic layers at a range of scales including field margins.*

In other words, we need to understand the inter-relationships between crop management and biodiversity if we are to assess longer-term and larger-scale impacts of GMHT cropping on biodiversity. A second project workshop to consider these issues is planned for late February 2001.

### **Planning for publication of the final report**

The four crops are being considered as independent experiments, but with common methods, analyses and forms of interpretation. For each of the crops, the report could take a structure such as:

*Introduction, and (brief) review of methods*

*Site selection*

*Crop management*

*Seedbanks*

*Weed populations*

*Plant population dynamics within fields*

*Field margin vegetation*

*Within-field invertebrates*

*Field margin invertebrates*

*Bees and butterflies*

*Crop management, vegetation and invertebrate community structure*

*Integrated assessment of the ecological impacts of managing GM crops*

*Conclusions and recommendations*

These could form the chapters of a journal special issue. This list will evolve as the project develops, and as data analysis proceeds.

Scientifically, it would be valuable to report at least some of the crops simultaneously, possibly within the same papers. However, the individual crop research programmes do not conclude at the same time: the winter oil seed rape programme is due to conclude nearly a year after spring oil seed rape and maize. We wish to discuss this issue of reporting with the SSC.

## **8 PUBLICATIONS TO DATE:**

### **8.1 Refereed Journals**

Firbank, L.G., Dewar, A.M., Hill, M.O., May, M.J., Perry, J.N., Rothery, P., Squire, G. & Woiwod, I.P. (1999). Farm scale evaluation of GM crops explained. *Nature*, 339, 727-728.

Firbank, L.G. & Forcella, F. (2000). Genetically modified crops and farmland biodiversity. *Science*, 289 1481-1482.

## 8.2 Other publications

Firbank, L.G. (2000) Science meets policy: farm scale evaluations of genetically modified crops. *NERC News, Spring 2000*, pp 10-11.

Schuler, T. H., Poppy, G. M., Woiwod, I. P. & Denholm, I. (2000) Impacts of GM plants on non-target arthropod fauna. In *WHO Seminar " release of Genetically Modified Organisms in the Environment: is it a health Hazard"*. Rome, Italy, 7-9 September 2000: <http://www.who.it/Emissues/GMO/gmos.htm>.

Woiwod, I., Dewar, A., Hawes, C. & Heard, M. (2000a) Farm-scale trials for studying the effects of GM herbicide-tolerant crops on farmland biodiversity in the UK. *Antenna* 24, 66-68.

Woiwod, I. P., Dewar, A. M., Haughton, A., Hawes, C. & Heard, M. (2000b) UK field-scale trials of GM herbicide tolerant crops to detect the environmental effects on invertebrate abundance and biodiversity. In *XXI International Congress of Entomology*, vol. 1 (ed. D. L. Gazzoni), pp. 314. Foz do Iguassu, Brazil: Embrapa.

## 9 REFERENCE

Carroll, R.J. & Ruppert, D. (1998) *Transformation and Weighting in Regression*. Chapman & Hall, London.