GM Science Review : First Report
Comments by the British Trust for Ornithology.

BACKGROUND

The BTO contributes to the conservation of birds and their habitats through establishing, through scientific research, the facts and principles needed for informed decision-making. It was the first to identify the widespread and general losses of farmland birds; it has conducted much of the research that has illuminated both the causes of those declines and the impact of various farming systems. While it draws evidence to public notice, it does not campaign on issues. Nor does it comment on matters of policy (unless they impinge on its science) beyond pointing out the likely consequences of particular policies, insofar as its ecological expertise justifies such comments. However, our comments on the Report are, therefore, made on the basis of wishing to see the best possible scientific assessment being available to policy makers.

The BTO has little particular expertise on GM crops. However, it does have extensive experience in a wide range of farmland bird research, particularly with respect to understanding and impact of changes in farm management practices on their ecology, breeding biology and population trends. BTOs research has progressed from documenting and quantifying the extent of population declines and range contractions of farmland birds, to understanding the causes of these changes and, now, developing and field testing habitat management action that will serve to stem and ultimately reverse these declines. This research has been funded by a range of organisations including Defra, JNCC, BBSRC, NERC, Leverhulme and Unilever.

In recent years BTO has undertaken detailed research on aspects or arable crop management such as undersowing, organic farming, set aside and field margin management stubble retention. The Trust also led on a Defra-funded project (BD1618) reviewing action required to meet the farmland bird PSA target (Aebischer N.J. *et al.* 2002 Predicting the Response of Farmland Birds to Agricultural Change. *BTO Research Report* number 289; Vickery, J.A. *et al.* in press. The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. *Biological Conservation.*). In April 2000 the BTO was contracted to undertake an assessment of the feasibility of using the FSE to study potential impacts of GMHT crops on birds – the report of which is cited in this review Chamberlain et al 2001 (see our response point 6).

GENERAL RESPONSE

We congratulate the Panel on the production of a thorough and well-balance review of such a complex and controversial topic.

POINTS OF PARTICULAR AGREEMENT

We agree with most of the points made in the Report but particularly the following:

1 "The largest gap in our knowledge is the impact that GM HT cropping would have on biodiversity." (p.161)

2 "GM crops … could mean either benefit or harm to biodiversity, depending on the farmers' objectives, and market and policy drivers." (p.178)

This is perhaps the most important point for people to understand about the environmental impacts of GM crops. We fully support the last paragraph of section 6.5.3 (p.159)

3 "If we want GM pest-resistant plants to contribute to 'sustainable' agricultural systems, their impacts on food webs and ecosystem dynamics must be understood and translated into integrated pest management practices that can be carried out by farmers." (p.132)

" Were GM HT crops commercialised in the UK, it is largely unclear how they would be adopted." (p.162) So we need "to monitor uptake and application of new technologies in general and GM crops in particular". (p.183)

"*Agronomically realistic* [our emphasis] ecological studies comparing the impacts on biodiversity of the use of GM pest resistant crops with conventional insecticidal crop treatments should be undertaken for any GM pest-resitant crops that are being considered for commercial release in the EU." (p.134)

This issue of the need for studying the effects of the technology as it is used in commercial practice is of great importance.

4 The environmental impacts of particular agricultural technologies are difficult to predict and to study; simplistic arguments are invalid.

Section 6.5.3 of the Report brings this out clearly, though the point applies to all agricultural technologies, not just GM HT crops.

We note from that section in particular:

- The difficulty of teasing out the impact of one particular technology from the whole range of factors acting. (p.156, 5th paragraph).
- ".. impacts of herbicides on non-target biodiversity are not necessarily related to the amount of herbicide used, but to the efficacy and timing of the use of the herbicide concerned, so we must be careful not to confuse inputs of herbicides with their impacts." (p.152)
- The place of agriculture in the landscape is very different in N. America and in the UK (p.158, 3rd paragraph). This means not only that the ecology is different but that the socio-economic and political milieux are different.

5 "FSEs will not answer all outstanding scientific questions." (p.162)

".. it is unlikely that the FSE programme will address all of the concerns about

GM crops." (p.163)

6 "Should GM crops be commercialised, this monitoring must continue to ascertain their impact on biodiversity." (p.162)

"The post market monitoring could be an important contributor to the overall understanding of environmental effects as the products are used in practice, in the event of commercial approval. Appropriate measures and indicators for simple and robust monitoring systems could prove valuable both for practical application and to test and improve generalisable mathematical models." (p.163)

We believe that post-marketing monitoring is essential if the use of this (and any other) agricultural technology is to be adaptively managed.

7 a) "More field research on the impacts of pest- and disease-resistant GM crops on soil microorganism and processes should be carried out in advance of commercialisation." (p.135)

b) We need to study impacts over entire rotations. (p.162, last paragraph).

These are among the most striking gaps in knowledge that show little sign of being filled.

8 The introduction of GM wheat and grass could have particularly major impacts (p.163, 4th paragraph).

SUGGESTIONS FOR IMPROVEMENT

1. Critical approach to the literature

We believe that the Report has, at least in places, not adopted a sufficiently critical approach to the references it has quoted.

We have not made a full systematic assessment of the literature on the environmental impacts of GM crops but we believe that its overall quality is poor. There is:

1. A small amount of fairly direct evidence, based on scientifically valid methods and published in peer-reviewed journals.

2. Rather more indirect evidence, ranging in quality from Watkinson *et al.* (2000) (which is based on established facts, a formal model, and clear assumptions) to arguments based on simplistic assumptions (such that the lesser need for pesticide sprays on Bt crops than on conventional crops means that Bt crops are better for non-target fauna). Unfortunately, Watkinson *et al.'s* paper is almost unique in its quality and the simplistic arguments dominate this part of the literature.

3. Some unrefereed literature, often conference proceedings, that is quoted as evidence but which provides no more than scant methodological and statistical detail.

4. Much anecdotal "evidence", which on examination turns out merely to be based on impressions and hearsay. In some cases, the authors prove incapable of stating the source of their "information".

5. Much secondary literature that presents generalizations apparently based on other publications which, on examination, turn out merely to present the same generalizations. If one traces back through successive quotings, the original "evidence" often turns out to be mere anecdote.

In summary, there is a mass of published material but it is based on little hard evidence. However, we have ourselves looked at only one small area in our investigation of this issue (Annex 1).

The area at which we have looked involves exaggeration of evidence by the "pro-GM" lobby but we have no reason to suppose that there is not similar exaggeration by the "anti-GM" lobby. Our criticism is a matter of principle, not one of taking sides.

2. Critical approach to statistical analyses

Where papers on the environmental impacts of GM crops present data and subject it to formal statistical analyses, the approach is generally naïve. It is almost entirely based on the testing of null hypotheses of "No effect".

Particularly when the work is based on rather small samples, this seriously biases the studies towards reaching conclusions of "No effect". Given that the public concern is that there are adverse effects, this is an odd approach. We discuss the matter in more detail in Annex 2.

We believe that the Panel should look more critically at the statistical underpinning of reports of "No effect".

3. Monitoring

We believe that the report does not currently place enough weight on the value of monitoring and that it may exaggerate the difficulties.

We agree that it will be difficult to detect the impact of the commercial introduction of GM crops on biodiversity through monitoring. However, we believe that thought should be given to the possibilities for assessing the impacts of GM crops through a process of experimental commercial introduction before full commercial release is undertaken, with experimental and control areas being of hundreds or thousands of square kilometres (say, local government Districts). We recognize that such an approach may be difficult to implement in practice, although we have shown that the BTO/RSPB/JNCC Breeding Bird Survey is capable of monitoring a relatively large number of species on Environmentally Sensitive Areas (Noble, D. and Newson, S. 2002 Pilot work to assess bird occurrence and abundance on BBS squares within ESAs. *BTO Research Report* 300), a task of similar magnitude. In any case, it is for the scientific community to propose the most cost-effective approach to such work and for others to determine whether it would be politically and financially acceptable.

It is true that there has been little direct attempt to monitor the impact of individual agronomic practices until now. Even expensive schemes designed to provide environmental benefits have been poorly evaluated (Kleijn, D. & Sutherland, W.J. in press. How effective are European agri-environment schemes in conserving and promoting biodiversity? *J.appl.Ecol.*). However, the latter authors argue powerfully that evaluation of the effectiveness of such schemes should become an integral part of their introduction and the same applies to the monitoring of other major agricultural developments, such as GM crops.

4. Climate change

The Report refers to insect pests that are not currently a problem in Britain (pp.121, 141). For purposes of horizon scanning, it should be noted that these may become pests under likely scenarios of climate change.

5. The need for field trials.

The Report suggests that there are circumstances in which it is not necessary to undertake field trials as part of the risk-assessment procedure (Diagram 6.1; p.133, paragraph 3). For example, if lab/greenhouse experiments show no adverse effects on population dynamics. Given the hugely greater complexity of the real world than of the greenhouse, we doubt the wisdom of omitting field trials. To do so is logically equivalent to banning a crop just because lab work has indicated adverse effects. In either case, the lab/greenhouse work is merely a pointer to the sort of field study that is needed.

6. Indirect effects

We do not feel that Sections 6.5 and 6.6 place enough stress on the point that the environmental impacts will be largely indirect and that they will, in simple terms, be through changes in what is grown, where it is grown, and how it is grown.

On Page 157, the Report states that "*Direct experimental evidence linking the declines of farmland birds to increased levels of herbicide use is available only for grey partridge*" ...and also that there is strong circumstantial evidence to suggest that declines in weed seed resources will exacerbate farmland bird declines. Both statements are true but it is also true that recent studies have added to the evidence for indirect effects of pesticides on birds in the breeding season. In particular, studies on Corn Bunting and Yellowhammer have shown clear links between pesticide use and foraging behaviour of adult birds feeding young. For both these species, birds concentrate their foraging effort in cropped areas that have received relatively low levels of pesticide applications and support relatively high invertebrate numbers. (RSPB 2001. Indirect effects of pesticides on birds. In: Conservation Science in the RSPB 2001, p29. RSPB, Sandy; Brickle, N.W.*et al*. 2000. Effects of agricultural intensification on the breeding success of corn buntings *Miliaria calandra*. Journal of Applied Ecology 37, 742-755).

7. Farm-Scale Evaluations : the work on birds

The report by Chamberlain *et al.* (2001, *not* 2002) did *not* show that the FSEs "are too small to assess the impacts on birds". To quote from the Executive Summary of that report:

> *In summary, the power analyses presented here indicate that a high probability of detecting significant differences in bird abundance or occurrence between treatments would be possible for six species with the additional sites proposed for 2001. Point counts recording foraging individuals on maize and rape 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.*

Given those findings, it is strange that the work on birds was not continued for the full three years of the FSE programme.

8. Farm-Scale Evaluations : statistical power

The FSEs will present more refined statistical analyses than does most of the literature in this area (see Annex 2). They will probably have "adequate power (>80%) to detect multiplicative differences of R=1.5-fold".

However, suppose that a reduction in weed-seed abundance of 25% is estimated but is not significantly different from the null hypothesis of "no reduction". We can envisage that such a reduction could have either a subproportional or a superproportional response on bird populations. In its future assessment of the results of the FSEs, the Panel should assess the potential ecological significance not just of the statistically significant results but also of the non-significant ones.

9. An omission?

The Report does not include any consideration of GM biocontrol agents, some of which are being developed to control agricultural pests. We acknowledge that this subject is somewhat peripheral to the main thrust of the Report but believe that it should at least be flagged up as an area of concern.

Annex 1 Critical assessment of literature quoted in section 6.6.4, subsection on insect resistance (i.e. environmental impacts).

We have chosen this example haphazardly: it happens to be the section that we were reading when we began to wonder how critical had been the assessment of the literature used in the Review. We are unable to say how typical are these two paragraphs of the rest of the review.

The relevant conclusions reached in this subsection of the Review are:

IR Crops have :

- Resulted in reduced insecticide use
- Had neutral or positive effects on non-target fauna

(Also conclusion on insect resistance management tools but we have not considered this).

We have reviewed all the references quoted in this subsection of the report (except those on insect resistance management) and our comments are as follows, except for those on Losey et al. (subsumed under remarks on the monarch/swallowtail experiments – see Carpenter et al.). We have included comments on two major papers not directly quoted in the Review but used in two of the web-contributions that the Review refers to.

Carpenter *et al.*, 2002 (Comparative Environmental Impacts of Biotechnology-derived and traditional Soybean, Corn and Cotton Crops. Council for Agricultural Science and Technology, Ames, Iowa).
This is a major review. We refer here only to what it has to say about the environmental impacts of GM IR crops.

Bt corn

The Executive summary states:

> Bt corn can enhance the biodiversity of cornfields because beneficial insects fare better here than when conventional cornfields are sprayed with insecticides. Moreover, field studies of biotechnology-derived corn show that populations of beneficial insects are not adversely affected.

However, this overstates what appears in the full text of the report.

Under impacts on natural enemies (of corn pests), the full text summarizes various lab studies and small-scale field trials and concludes that there are no adverse effects. However, there appear to have been no studies of large-scale, commercial plantings and there is no indication of the power of the statistical tests used in the studies that have been done (see our comments on hypothesis testing, Annex 2)).

In respect of impacts on other non-target species, the text has three components. First, a review of the adverse effects of traditional pesticides and, second, a review of the adverse effects of Bt sprays; these points are, of course, relevant only if there is evidence that Bt IR corn cultivation has lesser effects. The third element is a review of the various experiments on the effects of Bt corn pollen on the larvae of monarch and swallowtail butterflies, which concludes (and we agree) that it seems that the likelihood of adverse effects on monarchs at the population level are likely to be small.

Bt Cotton

The Executive summary states:

> Bt cotton has been documented to have a positive effect on the number and diversity of beneficial insects in cotton fields in the United States of America.

There is actually no evidence of such positive benefits in any peer-reviewed publications that we have so far been able to find. The text of Carpenter et al. adduces 4 lines of evidence, as follows.

First, that traditional insecticides are toxic to many non-target species (see remarks above).

Second, that insecticide volumes used on US corn have substantially declined, which seems well established. (Carpenter *et al*. appear to assume that this will benefit non-target species without critically assessing the likelihood of this).

Third, that lab tests have shown no significant impact of Cry1AC proteins to predators.

Four, that other papers have shown that there are beneficial effects. Carpenter *et al.* refer to three such. The first is a publication by the International Cotton Advisory Committee, which states "field observation studies of the impacts of Bt cotton on non-target organisms have shown increases in populations due to the reduction in non-specific pesticide use" – but which gives no details or references. The other two are short papers (2-3 pages) in the Proceedings of the Beltwide Cotton Conference of 2001. We have not seen these as they are available to the pubic only on an expensive CD but we believe it unlikely that they present sufficient methodological or statistical detail to be regarded as significant scientific evidence.

Phipps & Park, 2002
Clearly establishes reduced insecticide (and herbicide) use in countries where GM crops have been planted commercially and estimates likely reductions in the EU if commercial cultivation were to take place. (Also, reduced fuel use and, therefore, CO_2 emissions).

Pimentel & Raven, 2000
This is a commentary rather than an original research paper. It reviews the studies made of the toxicity of Bt pollen for monarch and swallowtail butterfly larvae and comes to the conclusion that, while toxic effects are demonstrable in the lab, their impact in field situations is "relatively insignificant compared with other factors".

While this conclusion may well be correct, it adds no additional evidence to that adduced in Carpenter *et al.* (above).

Musser & Shelton, 2003
A report of field-scale trials that found Bt sweet corn to give "outstanding control of the lepidopteran pests" but no statistically significant reduction in the numbers of natural enemies of such pests. (But see our remarks on hypothesis testing, Annex 2).

Gregory *et al*., 2002
Although entitled "Environmental consequences of alternative practices for intensifying crop production", this paper concentrates on the physical environment, with only brief references to biota. Its section on the impact of GM technology is an expert assessment, concluding in respect of insect resistant GM varieties that benefits may be achieved through greater efficiency of agrochemical use and especially through reducing the need for farming systems with low external inputs to change their practices. However, it presents no data on the actual impact of IR GM crops on non-target species.

Gianessi *et al*., 2002
Although this covers 40 case studies, only 8 of them involve GM crops that have actually been adopted and only 2 of these refer to insect resistance.

The first states that Bt corn has increased US corn yields but does not claim that insecticide use has decreased, just that it has not increased.

The second states that Bt cotton reduces insecticide use, though no data are quoted and no information is given on changes in active ingredients or killing power.

Carrière *et al*., 2002
This shows that the use of Bt cotton suppressed populations of pink bollworm at a regional scale and suggests that it may also contribute to reducing the need for insecticide sprays. It did not adduce actual evidence for changes in insecticide use.

Thomson, J. 2001
This is a news item that states that the use of insect-resistant cotton in S. Africa reduces insecticide use, and causes increases in non-target insects, birds and frogs. However, the author tells us that this was based on anecdotal information, not on published data, except for the reduction in insecticide use. (J. Thompson, in litt. 10 Sept. 03)

Footnote 6, Web contribution by Halford
Merely summarises Gianessi *et al*.

Footnote 7, Web contribution by Michael
Merely summarises Phipps & Park and Gregory *et al*.

Footnote 8, Web contribution by Monsanto
Merely quotes Gianessi *et al*., Phipps & Park, and Carpenter *et al*.

Footnote 9, Web contribution by Leaver
This does *not* show reduced pesticide use.

Annex 2 : Hypothesis Tests And Statistical Power

The traditional hypothesis testing approach is inadequate to support much ecological investigation and is seriously misleading in the way in which it is being applied to the study of the environmental impacts of GM crops. There are two problems.

Firstly, in most (perhaps all) of the studies reported on the environmental impacts of GM crops the sample sizes are too small to deliver adequate statistical power. As an example, we refer to a particularly careful study, that of Wraight *et al*. (2000) into the toxicity of Bt corn pollen for Black Swallowtail caterpillars (PNAS 97 (14), 7700-3). Sample sizes used to estimate survival rates under different treatments were 48 caterpillars per treatment. If two treatments result in survival rates of 70% and 90% (a biologically large difference, we suggest), the sample size needed to detect that difference at the conventional 5% significance level with 95% power is 183, almost 4 times greater than that used. It is true that, in this particular case, there would be some increase in power if there were a simultaneous comparison of the several (rather than just two) treatments used but this is unlikely to be sufficient to mean that the sample sizes were adequate.

Even where power analyses are carried out, they typically utilize values of β (the complement of power) greater than the value of α (the significance level, usually 0.05). This is because of the view that it is worse to reject a correct null hypothesis (a Type I error) than to accept a false one (a Type II error). But is this true when the Null Hypothesis is that a particular agronomic practice has no environmental impacts compared with traditional practice? Is accepting that view (hypothesis) when it is false not as bad as rejecting it when it is true? We suggest that, in the absence of a formal procedure that takes into account the relative costs of these wrong decisions, it is appropriate to set $\beta=\alpha$, as above.

[Note that the FSEs have been the subject of power analyses (Perry *et al*., 2003, J.appl.Ecol. 40, 17-31) and that these have covered a range of possible effect sizes and of sample sizes. Even these, however, focus attention on a power level of 80%, not 95%].

The second inadequacy in the way in which hypothesis tests are applied in assessments of the impact of GM crops on biodiversity is that the hypotheses tested miss the point. They use the traditional Null Hypothesis – that there is no effect. In practice, whatever the strictly correct view as to what one should conclude when one finds that there is no significant difference, people tend to conclude that there really is no difference. But this possibility is not the real object of the investigation, which is to consider whether the effect (if any) is greater than a certain value. Surely it is this that should be set up as the Null Hypothesis, particularly if the precautionary principle is to be adopted.

Testing both hypotheses (“No effect” and “Effect greater than X”) is an approach of perhaps even greater value, in that the four possible results allow more useful conclusions:

“No effect”	“Effect > X”	Conclusion
accepted	accepted	Study powerless to distinguish an important effect size from no effect
rejected	rejected	Effect too small to be concerned about
accepted	rejected	Ditto
rejected	accepted	Effect large enough to raise concern

In practice, similar conclusions would follow if one simply made a point estimate of the effect size and placed confidence limits on this. Whether or not the confidence limits overlap effect sizes of zero and X then provides an immediate test of the two hypotheses. This is rarely done in the literature of the environmental impacts of GM crops, though we understand that it will be part of the reporting of the FSEs.

We would also advocate considering a Bayesian approach to this problem [see, e.g., Ecological Applications 6(4) 1034-1103 (1996)]. This would provide a conceptually sound approach to decision-making and adaptive management of the introduction of GM crops.

The Bayesian approach is often criticized because there is the possibility of disagreement about the prior probability distribution of the relevant effect size to employ. We consider this to be a strength, in that one can canvass opinion about the prior distribution and then consider a range of such possible priors. If the posterior distributions that result from different priors are substantially different, this means that the study in question has been insufficiently powerful to distinguish between the possibilities. If they are similar, this means that all parties, whatever their prior prejudices, should accept the estimates.

The Bayesian approach is also well suited to the sort of hierarchical approach set out in Diagram 6.1 of the report. Each level in the hierarchy provides a prior distribution for the next level in the sequence so that, for example, the conclusions from field trials are automatically informed by the conclusions from the greenhouse experiments.