Pesticides and the Living Landscape

by Ruth and David Barker

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(After Rudd, 1964)

David Barker BSc Hons Ecology, MIEEM
Ruth Barker MA Landscape Design, PhD
independent research and conservation practice

Correspondence: db.ecologist@gmail.com

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Preface

"*Neonicotinoids – From Zero to Hero in Insecticide Chemistry*" claimed Bayer Crop Scientists, Peter Jeschke and Ralf Nauen, in their paper published in 2008 in Pest Management Science (Jeschke and Nauen, 2008). In this manuscript the authors seek to indicate quite the reverse: – In terms of Biodiversity, Not Hero, but Zero! We ask "Is the Crop Protection Industry creating another Silent Spring?" (Barker and Barker, 2011). The claim that these insecticides are "better for the environment" than the earlier pesticides is not borne out by any evidence that biodiversity is being increased; in fact it continues to decline. We also refer to Krebs et al (1999) for another interpretation of a second Silent Spring.

This manuscript reviews a wide range of other published literature on the contentious subject of the widespread use of pesticides, in particular neonicotinoid insecticides, and demonstrates links between these latter and the accelerating decline in biodiversity in the UK and elsewhere since their introduction nearly twenty years ago.

We have been questioned about our motives: why go to the trouble of compiling this manuscript? Two main reasons:

Our own experience and observations over the last four years, of our conservation project in central France, of 10 hectares of meadow, pasture, oak/hornbeam coppice, coniferous woodland, with pesticide-free conditions both on our land and in the surrounding countryside, allows us to observe what the absence of the use of pesticides does offer. While some of the focus of this manuscript is on insecticides, in particular neonicotinoids, however, there is no doubt that the use of herbicides also has enormously reduced the flora within and adjacent to cereal fields and, as the ecologist Norman Moore, even in 1962, wrote "The total ecological change must be immense" (Moore, 1962, cited in Potts, 1986). We therefore in this manuscript attempt to bring the issue of pesticides to wider public attention and to offer evidence that the annihilation of natural habitats is due to the modern intensification of agriculture and the use of these chemicals.

The second is to do with the reactions we have found to our raising the question at all

The case for pesticides has frequently and forthrightly been put elsewhere, (Cooper and Dobson, 2007) including, by the manufacturers, a concentrated campaign, it might appear, to suppress opposition. This manuscript seeks not to repeat these arguments and benefits, but to put the other side of the case in relation to the health of the environment and other species, The risk to human living is of course also part of the subtext – though public awareness and understanding, whether among professionals in the business or lay people, of their dangers, seems absent. We think the issues of pesticides are perhaps best termed an "inconvenient truth". We refer to the eminent Professor Derek Bryce Smith who was the first to draw attention to the dangers of lead in petrol but was ridiculed and marginalised for decades.

This subject of pesticides and their effect on the living landscape is long and complicated and links together many fields which may usually be discussed separately. Our enquiry followed a number of phases on the road to accurate information and understanding. We have delved into the history of pesticides as well as current research on their effects. The result is a longer, more dense, manuscript that we intended or wanted – we ask the reader's patience to stick with it so that the connections and implications we are trying to show may become clear. It takes time to digest the material and its manifold implications

Abstract

The purpose of this manuscript is to bring to public attention the serious questions that have been raised about insecticides, particularly the systemic insecticides known as neonicotinoids, which are currently the most important insecticides for agricultural and horticultural pest control. The active chemical in neonicotinoids works by interfering with the transmission of stimuli in the insect's nervous system. It is not only pest insects which are affected: it can have destructive effects on non-target invertebrates such as bees, butterflies and other vital pollinating insects, and on birds, particularly those that consume invertebrates. Earthworms and other soil biota can suffer sub-lethal effects due to leaching of neonicotinoids into soil. Groundwater is an important source for drinking water in the European Union, and needs protection against contamination by surface-applied pesticides such as neonicotinoids. Neonicotinoid insecticides were introduced 20 years ago, yet field research of their impacts on non-target species and the soil and aquatic environments has rarely been undertaken.

In the course of this present enquiry we have become aware of a number of failings and weaknesses in the way the subject of any type of pesticides has been handled by responsible public bodies, both governmental and charitable, by academics, the chemical industry, the national press and feel it is right to draw critical attention to these matters.

We draw attention to the singular lack of investigation and communication of knowledge, and of resulting action, on these potentially very harmful but already widely used substances, and we point to the value of redefining terms of significance for decision-making, to recognise that indirect effects are as "devastating" as direct effects, and that "sub-lethal" may be just as "destructive" to a species as a "lethal" effect.

There is also the fact that in the last twenty years or so the chemical industry has not only developed their products exponentially (10 companies have multi-billion-dollar pesticide sales), but also has taken the centre ground – somehow not only avoiding criticism of their products and workings, but gaining acceptance of this without any serious questions being asked[1]. Since the vigorous and intelligent opposition in the 1960s, 70s and 80s from biologists and others in both Britain and the United States, these new pesticide products seem to have crept up on society unawares. We note particularly "generational amnesia": we have all got used to the incredibly poor agricultural environment we live in and the lack of life in farmland.

Even many of the environmental charities seem not to have made connections as to the effects and impacts of these chemical substances: each charity is set up to support one set of species staffed by specialists in that one area – the effect on the wide spectrum of species seems to be no-one's responsibility.

In 2000 The Royal Society for the Protection of Birds (RSPB) purchased Hope Farm in Cambridgeshire. Their aim was to demonstrate that it is possible both to be a profitable conventional farmer and to support a wealth of biodiversity. We ask why RSPB are not practising alternative farming methods, such as organic, or less intensive, given that research shows agri-environment schemes have had no measurable benefit on increasing the number of farmland birds on conventional farms.

We note evidence of the abject failure of the various agri-environment schemes to provide enough seeds for farmland birds to survive the latter part of the winter and the lack of monitoring by Defra to ensure farmers either have the right type of scheme or indeed whether farmers have even implemented the schemes for which they have received grants.

We finally would point to the limited attitudes (the problem of incompetence and ignorance) of the national press. We have had comments such as this from the environmental editor of a national newspaper after sending him a manuscript on neonicotinoids “there is nothing in it that is new, and in the end, newspapers are about news.”

We urge researchers, policy makers and everyone concerned with the natural environment, especially those involved in the protection and conservation of flora and fauna, to turn the peer reviewed, already published, research papers referred to in this manuscript into action.

1. Introduction

Two aspects of this debate need to be taken into account, primarily, the actual impact of pesticides and their effectiveness both on their intended target and on non-target organisms and the environment as a whole. Secondly, the way they are perceived, as helpful or otherwise, by the general public and how far they and their effects are acceptable or not. At the same time we would stress the vital need for the public to be educated, from the individual home-owner to decision-makers and to farmers, of the crucial role that all invertebrates play in our living ecosystem, not just the "attractive" ones.

When pesticides are brought to public attention, a great deal of confusion seems to be generated. Whom may one believe?

1.1 "Lies, damn lies and bee stories in the national press"

(National Farmers Union website (NFU, January 2011)

The NFU addressed its members:

> *"Many of you will have noticed a number of stories on honeybees and pesticides in the national press in the last month. The focus of most of the stories has been to expose evidence apparently linking a particular group of pesticides – the neonicotinoids – to the widespread decline in bee populations experienced across the globe in recent years. This coverage culminated last week in a discussion of this issue by MPs and Defra Minister Jim Paice in a Westminster Hall debate raised by Gower MP Martin Caton.*
>
> *"When you strip away the emotion, sensationalism and conspiracy theories surrounding this story about the impact of neonicotinoids on honeybees, you are left with the fact there is a pile of scientific studies suggesting causes for concern, and there is a pile of scientific studies saying there is no cause for concern. There is no clear weight of evidence linking any pesticides to the decline in bees." (NFU, 2011)*

In this manuscript, we wish to give prominence to the work of Robert Rudd, author of *Pesticides and the Living Landscape* (Rudd, 1964) who gave an early well-reasoned account of the impact of pesticides. This comprehensive and scientific account had to be respected by the pesticide companies and their supporters. We would emphasise the need for the national press to adopt similar reasoned accounts of the effects of pesticides on the theme of the "Living Landscape" rather than prompting the reaction of the NFU which claims "emotion, sensationalism and conspiracy theories". The national press generally display incompetence and ignorance so far as scientific aspects of the present topic are concerned. Their business is "selling newspapers" and "newspapers are about news" but this should not at the expense of the living environment.

Though honeybees seem to be the centre of the open public debate, in fact honeybees are only one organism impacted by pesticides. Rudd rightly states "We can no longer afford to dismiss piecemeal the "separate" problems that arise from uncontrolled chemicals in the living environment. There are no separate problems" (Rudd, 1964). Norman Moore (1964) in the foreword to the UK edition of Rudd's book drew attention to the differences in the use and control of pesticides between the USA and UK. Nevertheless Moore states “the ecological and philosophical ides in Dr. Rudd’s book are as applicable here as in the USA.”

1. 2 Pest and beneficial invertebrates

> “Herbivorous arthropods destroy approximately 25–50% of crops worldwide. The response to these threats by modern agriculture has been predominantly through the application of synthetic pesticides, a practice that has led to many unintended consequences including human health risks, degradation of ecosystem function, evolved toxicity resistance by pests, and severe alterations of the dynamics of agribusiness. The World Resources Institute estimates that over 400 pest species have evolved resistance to one or more pesticides, and that despite an increase in pesticide use, the proportion of crops destroyed by insect pests in the United States has doubled (to 13%) since the 1940s. By eliminating beneficial invertebrate and vertebrate predators through indiscriminate use of broad-spectrum insecticides, insect species that are not normally considered pests are often elevated to pest status” (Kunz et al, 2011).

2. Acceptability of pesticide impacts on the Environment

(see Appendix 1)

There are important links, not always straightforward, between pesticide

hazards and their regulation and public attitudes and opinions. The chemical industry's initial reaction to the early claim in the 1950s and 60s that organochlorine insecticides were causing damage to wildlife was to defend the status quo, holding on to this position for some time after the claim had been accepted by many reputable and impartial scientists and regulators (Moore, 1987, in Tait, 2001). "This industry response triggered a decline in public attitudes to, and trust in, the chemical industry from which it has yet to recover" (Bruce, Lyle and Tait, 2001 in Tait, 2001). "Such attitudes, once formed, are very difficult to reverse and the subsequent gradual improvement in the environmental and health impacts of pesticides has instead been seen by many members of the public as evidence that 'technical fixes do not work—they merely create new sets of problems for which we have to invent new fixes" (Tait, 2001).

European Union Directive 91/414/EEC includes the "key phrase" "that pesticides should have no unacceptable influence on the environment in general". In an important research project surveying public opinion, funded by the Department for Environment, Food and Rural Affairs (Defra), "*Acceptability of pesticide impacts on the Environment : what do UK stakeholders and the public value?*" Crane et al (2006) found "a substantial number of people, both among the general public and among a range of relevant stakeholders, interviewed with a number of methods including focus groups, are concerned about pesticide use; although pesticides are widely used in homes and gardens, their use on farm crops remains of concern. These concerns are greatest on issues of human health and food quality but potential environmental effects are also an issue particularly if attractive species could be affected".

As authors of the manuscript we are quite aware of, and have alluded to in the manuscript, the "tyranny of aggregation" where the risk of one pesticide can dominate within the popular press, for example the focus on neonicotinoids, where these have been featured and defended, as currently and most favoured in use.

Nevertheless many other pesticides have escaped public attention over the last 30 years.

Some practitioners suggest that the riskiness of neonicotinoids is neither greater nor less than that of other current insecticides such as the synthetic pyrethroids. Rather, they question how that risk should be mitigated or compensated for through management, bearing in mind that the risk arising from the other compounds can "demonstrably be mitigated or compensated for" (pers.comm. anon). Meanwhile the apologists for the manufacturers continue to bombard the public with their success stories, on a commercial basis. In a recent paper, Jeschke et al (2011) elaborate: "The unique success of neonicotinoid insecticides is reflected in their turnover figures in 1990 as compared with 2008.[2] " In our manuscript we attempt to bring back public attention to the risks and damage accompanying this "success". To offer an example of risk to human health and perception of that risk, a recent paper investigating the similarities between the discovery of and regulation of pharmaceuticals and pesticides points out that nearly every one has had an experience with pharmaceuticals and perhaps can relate to their benefits (Swanton et al 2011). On the other hand, pesticides are not personal and the benefits are not perceived as directly as those of a pharmaceutical by all individuals. The general public has very contrasting interpretations when it comes to comparing pharmaceuticals with pesticides.

"The work we did for Defra was greeted with a thunderous silence" says M. Crane (pers.comm.) Given that the four main points from the work of Crane et al, referred to above and outlined in Appendix 1 in this manuscript, included "societal values should play a role in regulatory decision making", we ask why has Defra apparently not followed up the recommendations in Crane and co-workers' paper?

While there are 40 negative articles published about pesticides for every one that has a positive view on them, Cooper and Dobson (2007) recommend "to maximise

the benefits of pesticide use at minimum human, environmental and economic cost, pesticides must be strictly regulated and used judiciously by properly trained and

appropriately-equipped personnel, ideally in tight integration with other complementary technologies". However there are also questions about the effectiveness of this regulation and usage. When government (Defra) commissions research on pesticide acceptability ((Crane, M. et al (2006) *Acceptability of pesticide impacts on the environment: what do United Kingdom stakeholders and the public value*? Pest Manage Sci *62*: 5–19 (2006)), and then greets the findings with a "deafening silence", it is little wonder that the public questions pesticide use over which they have little or no control.

Defra commissions and funds a number of Science and Research projects whose reports are difficult to come by for the general reader. These are in fact available on the internet, but not advertised; this seems to be called "grey literature". In a Defra Science and Research Project PS2313 Final Report Feb 2005- Oct 2006, with funding to the Game and Wildlife Conservancy Trust (see Appendix 5), "*Development of indicator species to measure pesticide impact on farmland wildlife*" the Executive Summary noted significant declines in invertebrate taxa after use of insecticides. Within this report, the following insecticides are mentioned, pyrethroids, non-systemic organophosphates, systemic organophosphates and carbamates (pirimicarb exclusively). There was no mention of neonicotinoids. Nevertheless, it is clear from this Report that knowledge of the potential impacts of insecticides on invertebrates has been sought and obtained by Defra.

It appears that Defra and other government bodies such as the Central Science Laboratory (CSL), now merged into Food and Environment Research Agency (Fera), and the National Bee Unit (all based at Sand Hutton, York) do undertake funding of various projects on this subject, but the way in which research findings are translated into changes of policy is opaque and does not appear to be consistent and the findings from these studies is difficult to come by for the general public who wish to be informed. In the two examples given above it appears that Defra do not follow up recommendations and, despite the many consultation processes, Defra pay scant regard to "societal values and concerns" or even to scientific evidence.

3. Pesticides

Since 1945 or so, it has become customary in Europe and America for farmers to apply chemicals to their field and crops, in the form of fertilisers and pesticides. This "Golden Age of Discovery" (Casida & Quistad, 1998) has been the source of most of our current insecticides. "An ongoing "wave" of herbicides in the 1960s, fungicides in the 1970s and insecticides in the 1980s" were used in Britain to control agricultural pests (Mellanby, 1970; Sheail, 1985; Moore, 1987). The newly discovered synthetic organic nerve poisons killed almost any pest, any time, anywhere (Casida & Quistad, 1998). Agriculturists viewed pesticides as a panacea, and some other long-used control methods (such as crop rotation and similar cultural controls) were abandoned in favour of applying ever-increasing quantities of pesticides that were seen to increase and ensure productivity.

The manufacturers these days now call themselves the "Crop Protection Industry" or "The Plant Protection Industry"! Nevertheless the pests are still with us. "Indeed" as Julian Huxley wrote "the very idea of extermination is unecological. It is almost certainly impossible to exterminate an abundant insect pest, but quite easy to exterminate non-abundant non-pests in the process".[3]

One toxicologist's comment on this was:

> "To a very large extent Darwinism applies as Julian Huxley implies. If a population is large enough and genetically diverse enough 'unnatural' selection will lead to the emergence of resistant strains which possess 'resistance' genes - typically within 10-20 generations with insects. This also applies to predators, although they generally exist in very small numbers in relation to the herbivores and omnivores upon which they feed, and probably have considerably less genetic variation within the population. Thus, they very likely are less able to develop strong resistance than herbivores/omnivores. This was probably a factor in the decline of sparrowhawk populations in E. England due to effects of dieldrin". Colin H. Walker (pers.comm.) and see Newton, (1986) and Sibly, Newton & Walker (2000).

Farming practices vary considerably, ranging from low-input (extensive) agriculture, including organic farming, where artificial inputs are strictly limited and perhaps avoided altogether, to high-input (intensive) agriculture, in which artificial fertilisers, insecticides, fungicides and herbicides may be applied routinely (Alford, 2011). In modern agriculture insecticides and fungicides are frequently co-applied in a tank mix. The application of tank mixes may pose a risk to honeybees by a synergistic enhancement of bee toxicity by the co-applied compounds (Schmuck et al, 2003).

There is also concern about the admixture of systemic compounds *within* the vascular system of plants when they are applied separately, for example in combinations of EBIs (ergosterol biosynthesis inhibiting fungicide) with neonicotinoids.

O'Connor and Shrub (1986) in their book *Farming and Birds* wrote about "chemical farming": "Pesticides (the generic term properly used to cover the whole range of farm herbicides, fungicides and insecticides) have three series of effects….". Among these effects they included both direct and indirect effects:

"Firstly, they (pesticides) kill plants and animals, often selectively, thus directly influencing the environment and its ecology: selectivity may be as significant ecologically as elimination.

"Secondly, they may change food and habitat resources, e.g. by removing weed species on which insect populations depend, and thus indirectly affect the numbers or distribution of forms immune to direct effects."

It is interesting that O'Connor and Shrub used the term "direct" when describing the impact of pesticides "influencing the environment and its ecology".

3.1 Direct and Indirect effects and lethal and sub-lethal effects of pesticides

We are concerned about the use of the terms direct and indirect effects and lethal and sub-lethal when assessing the effects of pesticides on wildlife. As Robert Rudd (1964) wrote, "It is my view that the scope of hazard from toxic chemicals is generally defined too narrowly. An illusion of safety follows (p.285)". For example, when birds suffer starvation as a result of invertebrate prey being destroyed, ecologists up to now consider all the effects of loss of resources as indirect ("a concept shrouded in mystery and controversy", suggests Judea Pearl (2005 and In Press)).

Is the effect of the pesticide a direct or indirect effect on the bird when the food source (the pest or other non-target invertebrate) for the bird is eliminated?
"I would say it is indirect effect, which does not diminish in any way its devastating effect, or its potential fatal effect. The indirect effect can be many times stronger than the direct effect" (Sharon Strauss and Judea Pearl, pers.comm).

Desneux et al (2007) state that "traditionally, measurement of the acute toxicity of pesticides to beneficial arthropods has relied largely on the determination of an acute median lethal dose or concentration. However, the estimated lethal dose during acute toxicity tests may only be a partial measure of the deleterious effects. Review of sub-lethal effects reported in published literature, taking into account recent data, has revealed new insights into the sub-lethal effects of pesticides including effects on learning performance, behaviour, and neurophysiology". In the relatively easy conditions of laboratory life, such effects might appear to be insignificant but, in the field, even a slight impairment in efficiency, or alteration in behaviour, might have important consequences (Sheail, 1985).
Thompson and Maus (2007) asked "What is meant by a sub-lethal effect? Which sub-lethal effects should be measured, when and how? How are sub-lethal effects to be included in risk assessments?" The authors conclude that "sub-lethal studies may be helpful as an optional test to address particular, compound-specific concerns, as a lower-tier alternative to semi-field or field testing, if the effects are shown to be ecologically relevant. However, available higher-tier data (semi-field, field tests) should make any additional sub-lethal testing unnecessary, and higher-tier data should always override data of lower-tier trials on sub-lethal effects." It is to be noted that Thompson is employed by Fera (the UK Government Central Science Laboratory, York) and Maus employed by Bayer Crop Science. One might ask questions in return: Why have Bayer not organised or undertaken more rigorous field testing of neonicotinoids? Why were the independent research findings of negative effects on bees not included in the Draft Assessment Report? Why is the Draft Assessment Report for the commonest neonicotinoid, imidacloprid, put together by Bayer, the manufacturer of the same imidacloprid? Why have the various UK

governmental bodies Defra, Fera etc. accepted Bayer's own report which also found no reason why it should not be approved?

Gary Heinz, in his paper "How lethal are *sub-lethal* effects*?*" (Heinz, 1989), concludes "Some day, perhaps many decades from now, we may regulate chemical problems differently. We may not permit chemicals that cause sub-lethal effects to get into the environment just because we do not like the idea of our fish and wildlife being abnormal, bur right now we do not regulate this way. Right now, we really do need to know how lethal sub-lethal effects are".

Indirect and sub-lethal may convey an impression of "a less harmful" scenario and yet both have the potential to cause death and/or behavioural changes that also may result in death. Many environmental studies and research papers do mention indirect effects and sub-lethal, but perhaps as having less value than direct and lethal - as if the former effects are acceptable. When carried over into the field, in reality they are not – an "illusion of safety".

3.2 The first insecticides

For the larger part of this manuscript we are focusing on just one branch of these chemicals: insecticides, those intended to kill insects. Later we shall discuss fungicides and herbicides, and the combinations in which these may be applied. The four major groups of insecticides which dominate the world market are pyrethroids, organophosphates, methylcarbamates and neonicotinoids.

Some early pesticides, such as arsenic and chlorine, and DDT (dichlorodiphenyltrichloroethane) introduced in 1939, (DDT was not used in Agriculture until after World War Two - probably 1946 in the UK) and the later organophosphates, methylcarbamates, and pyrethroids - all neuroactive chemicals - were extremely effective in dealing with pests, but they were also found to produce other undesirable and often destructive side-effects

The first public alarm about pesticides was sounded in 1962, even though American farmers had been spreading thousands of tons of the insecticide DDT during the 1950s and 60s. Rachel Carson, the distinguished American biologist, environmentalist and journalist, published her book "*Silent Spring*" to challenge their widespread use, by giving well-researched evidence. The episode of the poisoning of western grebes at Clear Lake in California by the use of DDD (a close relative of DDT), in an effort to reduce the population of a small gnat that was annoying fishermen, provoked the question whether it is desirable to use such substances especially when introduced directly into a body of water (Carson, 1962).

She established the link to waning bird populations, as DDT made its way through the food chain in ever-more-concentrated doses.[4] The US banned DDT in 1972 as posing unacceptable risks to the environment and potential harm to human health. In Britain, severe declines in populations of peregrine falcons and sparrow hawks became a "*cause célèbre"* for conservation (Wilson 2009). The decline of these raptors in Britain was due to cyclodienes, e.g. dieldrin (Newton, 1986 and Sibly, Newton & Walker, 2000). However, DDT was implicated in egg shell thinning in some British birds (Ratcliffe, 1970). Since then, the grey partridge *Perdix perdix* remains the only species for which the most incontrovertible evidence exists for pesticide-related decline (RSPB, 2008, Potts, 1986) – it appears no other bird has been studied in the same way.

Carson's book roused a storm of public protest and raised awareness of these and other dangers to the environment, as a wake-up call to ecological sensitivity. It continues to be referred to widely even if less well-read in detail. The result of the book was that controls and bans were introduced on DDT in many countries, and worldwide under the Stockholm Convention (but is still in use in parts of the world).

3.3 After Silent Spring - The neonicotinoids: Imidacloprid, Clothianidin and Thiamethoxam

Chemical companies have invested in developing alternatives with lower doses and more subtle effects, seemingly less harmful to the environment.[5] Agricultural use of insecticides has increased enormously, especially for the aim of "plant protection", but

> "most currently used insecticides and other chemicals for control of invertebrate pests in both agriculture and public health act through interference with the nervous system. As such they present few problems of phytotoxicity, but of all pesticides they present the greatest acute risk to the health of human beings and fauna in the environment" (Carlile, 2006).

The neonicotinoids are a new class of insecticides, available since 1993 (Moffat, 1993). Owing to the high systemicity (of neonicotinoids) diverse application techniques are feasible, and these methods have been introduced into practice – some of these methods even became only commercially possible with the introduction of neonicotinoids. (It should be noted that systemic insecticides are not new, and organo-phosphorous insecticides, e.g. Metasystox, have been around since the late nineteen forties (Mellanby, 1970)) Soil treatments can be done by incorporation of granules, injection, drip irrigation, spraying and the use of tablets. Plants or plant parts can be treated by seed dressing, pelleting, implantation, dipping, injection and painting (Jeschke and Nauen, 2008).
In the UK many of the neonicotinoid insecticides are used to treat seeds prior to drilling in the soil to at least a depth of 40mm. Spraying and any environmental impacts due to spray drift are usually associated with other types of pesticides.

3.4 Neonicotinoid Insecticide Toxicology[6]

While they appear to have many advantages, criticism has been raised since their introduction, criticism both of the use of the substances and of the way appropriate authorities have regulated this use. "They generally have low acute toxicity to mammals, birds, and fish, but display some chronic toxicity in mammals. The Environmental Protection Agency (USA) has not followed a cumulative risk approach in determining pesticide tolerances for neonicotinoids and has not assumed that each neonicotinoid has a common mechanism of toxicity with other substances. Of the commercial neonicotinoids, acetamiprid, IMI, and thiacloprid are the most toxic to birds, and thiacloprid to fish. Several neonicotinoids are harmful to honeybees, either by direct contact or ingestion, but potential problems can be minimized or avoided by treating seeds and not spraying flowering crops" (Tomizawa and Casida, 2005).

It is often claimed that a reduction in the quantity of the active ingredient applied to achieve a given effect means that newer pesticides are safer than their predecessors, but this could merely be an indication that they are more potent toxins (Tait, 2001). The neonicotinoids may seem ideal insecticides because application rates are much lower than for older, traditionally used, insecticides, but, unfortunately, there may be disadvantages as well which have not been thoroughly investigated. Henk Tennekes, a Dutch toxicologist, has recently published a book, *The systemic insecticides: A Disaster in the Making,* in which he warns of the dangers of their effects (Tennekes, 2010b). Having a systemic action (and being water-soluble), the chemicals are moved around in the vascular system of plants and thus are particularly effective against a broad spectrum of sucking and certain chewing pests. They do not however only affect these pests: any insect that feeds on the crop will ingest the chemical too, including beneficial predators of pests and also any bee or butterfly that collects nectar or pollen from the crop. In addition, neonicotinoids “bind irreversibly to critical receptors in the central nervous system of insects. The damage is cumulative, and with every exposure more receptors are blocked” Tennekes (2010a)[7]. Also see the response of Bayer Crop Science AG through Maus and Nauen (2011) who conclude that potential chronic effects of imidacloprid to honeybees are appropriately covered by the studies that have been conducted.

Though these chemicals are intended to “protect” crops from attack by “pest” insects which might threaten maximum crop yield, unfortunately, many “non-target species” are also affected, in other words, many other invertebrates in and beyond cropped lands (Moreby et al, 1997; Frampton and Dorne, 2007).

Many other non-target insect visitors, such as beetles, flies (particularly hoverflies), moths, ants, in addition to bees and butterflies, get a dose of insecticide *every* time they feed on the plant or visit a plant for nectar or pollen. Also, when imidacloprid is applied as systemic insecticide to the soil around plants and trees it may cause adverse effects on earthworms (Kreutzweiser et al, 2009, cited in Dittbrenner et al, 2010). “Since imidacloprid has a relatively high half-life in soil (over 1 year, Sabbagh et al. 2002), birds might be affected by feeding on contaminated earthworms, too! It is hard to predict how critical effects on birds are when contaminated via the food chain: the Ld50 (a dose at which 50% of subjects will die) in birds is in the range of 30-150mg/kg. However, I am not aware of any study focusing on this topic” Nils Dittbrenner (pers. comm.). He adds that further research, to be published shortly, indicates short- and long-term effects on burrowing behaviour in different earthworms after exposure to PECs (Predicted Environmental Concentrations) of imidacloprid Dittbrenner et al (In Press).

3.5 Water and Soil

Tennekes claims that neonicotinoid insecticides, such as imidacloprid, clothianidin and thiamethoxam, “are persistent and mobile in soil, soluble in water and stable to breakdown by water at neutral pH”. As a result of these properties, the compounds have “high leaching potential” and, in addition, imidacloprid degrades with a half-life of 355 days in some basic solutions. Thus, it can persist for much longer than a year. “We are dealing here with exponential decline. So, for example, if it takes 1 year to ` lose` half of a concentration,-- after a further year a half of the residual concentration will be lost -- a quarter of the original concentration will remain”. (Colin H. Walker pers.comm.). Tišler et al (2009) found that imidacloprid was persistent in water samples and not readily biodegradable in aquatic environment. As a result of their findings in the study they recommend additional toxicity and biodegradability studies of commercial products containing imidacloprid as an active ingredient in the aquatic environment.

It is in many European countries and elsewhere that evidence is being gathered and publicised in order to expose the dangers of these substances (Tennekes 2010b). Since 2004, major contamination of Dutch surface water with imidacloprid has been detected by the Water Boards, particularly in the western part of the country. Thiacloprid, like other neonicotinoids, has high water solubility and potentially may contaminate surface water following rainfall events (Beketov and Liess, 2008a). Beketov and Liess found that thiacloprid can cause delayed lethal and sub-lethal effects on freshwater arthropods at relatively low concentrations, which do not cause considerable acute mortality. Undoubtedly, these delayed effects are important for our realistic understanding of the toxicant’s ecological impact, because the difference between the LC50s found for negligibly short (1 d) and relatively long (11–30 d) post exposure observation periods was up to a factor of >50. Imidacloprid exposure has been found to reduce the survivorship, feeding, and egestion of mayflies and oligochaetes at concentrations from 0.5 to10 µg/L (Alexander et al 2007).

Downstream drift of lotic macro-invertebrates induced by toxicants is a well-known ecologically relevant phenomenon “The present results suggest that neurotoxic insecticides have pronounced drift-initiating potential, as all of the tested neurotoxicants initiated drift in stream microcosms….The neurotoxic insecticides that initiated drift in the present study were the pyrethroid fenvalerate and the neonicotinoids thiacloprid, imidacloprid, and acetamiprid” (Beketov & Liess, 2008b). The reduction of non-target insect species and other arthropods may thereby also reduce availability of food resources for birds, fish and other species and this limits mobility.

Further research adds to the picture: “Many pesticides bind strongly to soil and are therefore immobile. If the pesticide is not readily degraded and moves freely with water percolating downward through the soil, the likelihood of it reaching groundwater is relatively high. Leaching of pesticides to ground water is a cause of concern as the groundwater is the major source of drinking water especially in the developing countries. To ensure the safety of groundwater it is necessary to study the dissipation and mobility behaviour of pesticides before recommending them for agricultural use.” (Gupta et al, 2008).

3.6 Synergism

Other researchers are warning of dangerous effects of insecticides mixed with other pesticides, fungicides and herbicides, termed “synergism” (Pilling and Jepson, 1993; Pilling et al, 1995) both when applied together (the farmer’s tank mix) and non-simultaneous applications on the same land over a year or over many years. The ergosterol biosynthesis inhibiting (EBI) fungicide prochloraz can enhance the effect of other pesticides in a range of animal species (Nørgaard and Cedergreen, 2010). In their paper "*Pesticide cocktails can interact synergistically on aquatic crustaceans"* the extent to which this might create unforeseen ecological problems is discussed. Schmuck et al (2003) investigating the Field Relevance of a synergistic effect observed in the laboratory between an EBI fungicide and a chloronicotinyl insecticide in the honeybee (*Apis mellifera* L, Hymenoptera) found that the EBI fungicides prochloraz and tebuconazole strongly enhanced the toxicity of thiacloprid. Dis-coordinated movements, apathy and death were recorded in 87% and 70% of the treated bees, respectively.

3.7 Resistance

Meanwhile the manufacturers and Pest Management scholars point to the serious problems of pests when adapted to the low-dosed chemicals and the building up of resistance. The attitude of these researchers is shown in a report from the Global Workshop on the Stewardship of Neonicotinoid Insecticides, Honolulu, Hawaii,

> "Neonicotinoid resistance is everyone's problem and its long-term prevention and management is vital." (Nauen et al, 2008)

One solution is to increase the dosage to high levels. In *Low pesticide rates may hasten the evolution of resistance by increasing mutation frequencies*; Jonathan Gressel advocates the "need to consider 'Coup De Grace' technologies":

> "Thus, if indeed the seemingly logical hypothesis that stress increases mutation rates, leading to more rapid evolution of pesticide resistance, is found to be correct in direct experiments, resistance management strategies must be rethought. Somehow it must be assured that, when using ultralow doses, the sick pests be put out of their misery before they reproduce, bearing anarchistic mutant genes. Indeed, the conclusion may be reached that pest biodiversity within an agricultural field is not a good long-term management strategy, and indeed the concept of 'the only good pest is a dead pest' may be correct within farmers' fields." (Gressel, 2011b).

His concluding phrase is `within farmers fields`-- but the whole point is that for the majority of pests, which are invaders, (with the possible exception of` prairie lands) large numbers exist elsewhere, either in neighbouring countryside, field margins including beetle banks, or in other people's unsprayed fields. The selective pressure is applied to only a small percent of the total population of (perceived) pests - and in any case, the dose received by individuals can vary enormously over the sprayed area itself. Due to the high leaching potential of several neonicotinoids, the insecticide may not be just confined to farmers' fields, but to adjacent areas that were left in situ to promote biodiversity, possibly sustained by government grants.
Increasing the dose is not the only solution! (See below, section on Alternatives to Management by Pesticides*)*

3.8 The Pesticide Treadmill

The "pesticide treadmill" is a term used to denote three forces operating simultaneously, Pest Resurgence, Pesticide Resistance, Secondary Pest Outbreak (Perfecto et al, 2009; Vandermeer, 2011):

1) The fact that a pest will usually come back in force after the pesticide kills not only it but also its natural enemies

2) The unavoidable fact that pests evolve resistance to whatever poison is thrown at them
3) The surprising tendency of the pesticide to kill the natural controls of herbivorous insects that were not previously pests (because of those natural controls that have kept them from becoming pests earlier), causing these insects to reach outbreak levels

Each of these forces had been well-known even before *Silent Spring*, but they were put first together as a coherent whole by Robert Van den Bosch (Van den Bosch, 1978 and 1989).

3.9 European Farmland, Pesticides and Wildlife

Stoate et al (2001 and 2009) have written two comprehensive papers on European farmland "Ecological impacts of arable intensification in Europe" and "Ecological impacts of early 21st century agricultural change in Europe – A review". We consider both these papers explain what has transpired in the European farming landscape and the resultant impacts and what can be done to reduce these impacts.

A study published in 2010 by Geiger et al reported the effects of agricultural intensification on biodiversity across three trophic levels and the potential for biological pest control in eight European countries:

> "Out of the 13 studied components of agricultural intensification, use of pesticides, especially insecticides and fungicides, had the most consistent negative effects on the species diversity of plants, carabids and ground-nesting farmland birds, and on the potential for biological pest control. We conclude that despite several decades of implementing a Europe wide policy intended to considerably reduce the amount of chemicals applied on arable land, pesticides are still having disastrous consequences for wild plant and animal species on European farmland. Importantly, this impact is also manifested as a reduction of the potential of natural enemies to control pest organisms."

Their conclusion was that "if biodiversity is to be restored in Europe and opportunities are to be created for crop production utilising biodiversity-based ecosystems services such as biological pest control, a Europe-wide shift towards farming with a minimal use of pesticides over large areas is urgently needed".

4. Impact on non-target species and plants – some (of many) examples

Biesmeijer et al (2006) identified parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. The potential key drivers of these declines they claimed were climate change, habitat alteration and agricultural chemical usage.

If too many of these insects disappear, crops will have to be pollinated by hand - a labour-intensive practice that despite sounding far-fetched is already under way in China. Initial estimates put the additional cost of doing something similar in Britain at £1.5bn per year. (BBC Panorama, 30.8.10)

Buglife, the Invertebrate Conservation Trust, asserts its mission as " Conserving the small things that run the world". Robert Rudd in 1964, in relation to pesticides usage, put it this way:

> "The invertebrate animals comprise by far the largest number and variety of living things. In fact the phylum Arthropoda, which includes the insects, contains about ninety percent of all animal species. Terrestrial invertebrates are greater in number while aquatic forms include a greater variety. Most of our pests, parasites and disease vectors – the targets of pest control – are invertebrate animals. However important these species may be as pests, the majority of invertebrates can be looked upon as beneficial forms – at their simplest, interesting, and more finely analysed both economically desirable and truly necessary in the maintenance of animal food chains.
>
> "The complexity of the interactions between invertebrate animals and their physical and biological environment is perceived but incompletely understood by scientists." (Rudd, 1964)

In other words "Pollinator declines can result in loss of pollination services which have important negative ecological and economic impacts that could significantly affect the maintenance of wild plant diversity, wider ecosystem stability, crop production, food security and human welfare". (Potts et al, 2010).

In the following section, we begin with honeybees as the most widely published example, but go on to bring to attention some of the many other impacted species.

4.1 Honeybees

Concern about the negative effects of agricultural use of neonicotinoids has so far largely focused on honeybees. Beekeepers in a number of European countries have reported large losses of honeybees after nearby use of these neonicotinoids. The effects seem to be appearing widely in Europe and the United States of America. Panic about honeybee colonies collapsing, empty hives, a dearth of honey, and a shortage of pollinators for California's almond crop, has reached the media. This phenomenon has been called "honey bee vanishing" or Colony Collapse Disorder (CCD). These terms describe a state where the bees seem to lose their navigation systems (the forager bee stage) and which disrupts the working order of the bees within the hive. Many theories have been suggested for this including stress factors such as varroa mites, loss of habitat and climate change (Ratnieks & Carreck, 2010).

In honeybees, grooming is an important part of removing parasites such as varroa and of pheromone perception and transmission. The latter function is carried out by workers as they move through the colony after attending the queen and antennate other workers, presumably transmitting some of the queen's pheromones (Winston, 1987). Recently questions have been asked about neonicotinoids and honeybees' grooming because of a newly launched termiticide (The Independent, Wednesday, 30 March 2011, "Government asked to investigate new pesticide link to bee decline"). In its publicity material for Premise 200SC, Bayer says: "The termites are susceptible to disease caused by micro-organisms or fungi found in soil. A principal part of their defence system is their grooming habits, which allow the termites to get rid of the fungal spores before these spores germinate and cause disease or death. Premise 200SC interferes with this natural process by lowering defences to nature's own weaponry."

Separate research on termites (*C. cumulans)* studied termites' grooming behaviour and the effect when treated with entomopathogenic fungi and sub-doses of imidacloprid insecticide. In the first hours after fungal application, the termite workers showed an efficient grooming behaviour which allowed the removal of all conidia from the cuticle of soldiers and other workers. When the insecticide imidacloprid was added, even when used in sub-lethal concentrations, grooming behaviour was inhibited and allowed conidia to germinate and penetrate the insect cuticle, causing infection. "Thus our results show that imidacloprid affects *C. cumulans* workers' activity and the grooming capacity, allowing the permanence and later germination of the entomopathogenic fungi on the insect cuticle, improving the efficiency of these pathogens" (Neves & Alves, 2000).

If this were also applied to bees this could disrupt communication throughout the entire colony whether bees have ingested chemicals or not. In response to the Independent's questions, Bayer's UK spokesman, Dr Julian Little, commented "We do a lot of tests of the effects of insecticides on bees, and impairment of grooming has never shown up," but he added that specific tests to see whether or not bees' grooming ability was impaired by neonicotinoids had not been carried out.

For a thorough discussion of the puzzle of honeybee losses see Maini et al (2010) and Spivak et al (2011) for "The Plight of the Bees".

However, agrochemicals, particularly neonicotinoids, appear to be implicated in the decline because many CCDs appear to have occurred following spraying of fruit trees and other plants attractive to pollinating insects, including oil seed rape (particularly attractive to honeybees). Pollen and nectar contaminated by insecticides are brought back into the hive, fed to the developing brood, and consumed by all inhabitants of the hive – so the whole "super-organism" is weakened and more vulnerable to pathogens and parasites. A recent study demonstrates that the interaction between the microsporidia *Nosema* and a neonicotinoid significantly weakened honeybees (Alaux et al, 2010). In a further paper by Vidau et al (2011) *Exposure to Sublethal Doses of Fipronil and Thiacloprid Highly Increases Mortality of Honeybees Previously Infected by Nosema ceranae*, it was concluded, confirmed by their study, that "interactions between N. ceranae and insecticides constitute a significant risk for honeybee health. The increasing prevalence of N. ceranae in

European apiary combined with the constant toxic pressure undergone by honeybees, appears to contribute to the honeybee colony depopulation."

The agrochemical industry's research asserts that application at the very low levels of application which they recommend shows no significant harm to honeybees. However, Tennekes in his recent paper in Toxicology (Tennekes 2010a) makes the point that the toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time and questions whether the basis of research reaches widely enough. "The essence of the Druckrey–Küpfmüller equation states that the total dose required to produce the same effect decreases with decreasing exposure levels, even though the exposure times required to produce the same effect increase with decreasing exposure levels. Druckrey and Küpfmüller inferred that if both receptor binding and the effect are irreversible, exposure time would reinforce the effect. The Druckrey–Küpfmüller equation explains why toxicity may occur after prolonged exposure to very low toxicant levels……Traditional approaches that consider toxic effects at fixed exposure times are unable to allow extrapolation from measured endpoints to effects that may occur at other times of exposure." However, Maus and Nauen (2011), Bayer scientists, state "that there is no substantiation for concerns that effects like described by the Druckrey–Küpfmüller equation might entail a higher chronic toxicity than currently determined. In contrast, recent studies provide evidence that there is under realistic conditions no correlation between exposure of honeybees to imidacloprid-treated crops and increased colony mortality".

There is another controversy emerging about "guttation", the drops of plant-sap on leaves, (excretion of xylem fluid at leaf margins) such as grasses (including maize, wheat, barley etc.). When bees consume guttation drops, collected from plants grown (in the lab) from neonicotinoid-coated seeds, they encounter death within a few minutes (Girolami, 2009). As imidacloprid, clothianidin and other neonicotinoid pesticides are systemic - and present in the rising sap of the plants - the pesticides are expressed in these droplets. Further studies are required to ascertain if bees consume guttation drops in the field.

Four European countries have already suspended the sales of neonicotinoid pesticides to a "greater or lesser degree", two countries having banned the sale following massive honeybee kills associated with their use. One neonicotinoid insecticide launched in 1994, Gaucho®, having imidacloprid as its active compound, has been banned for use on sunflowers in France since 1999 (Bonmatin et al 2004).[8] In the UK however a Defra spokesman in October 2008 said there were no plans to ban the pesticides in the UK. The Soil Association took up the cause and urged the UK Government to ban pesticides linked to honeybee deaths around the world.[9] Buglife and other environmental organisations have called for a review and a precautionary suspension in the licensing of neonicotinoid insecticides for use in the UK, on the basis that they are considered damaging to bumblebees, honeybees and other non-target invertebrates. A report published by Buglife in 2009 highlights that the current process for approving crop pesticides is inadequate for assessing risks to bees and other invertebrates.[10] Scientific evidence Buglife presents shows that bees which eat nectar and pollen contaminated with imidacloprid (the commonest neonicotinoid) then forage less and produce fewer offspring.

This focus on harmful effects to honeybees, or not, as important crop pollinators, appears to have distracted attention away from the many other important losses in biodiversity. While the debate rages about the cause(s) of honeybee losses, the pesticide manufacturers, who invest a great deal of money in research to protect the use of their product, can divert criticism towards other "culprits", varroa*, Nosema,* miticides used in hives, habitat loss etc. As a result of this debate, meanwhile, more independent, government and other, funding is now being directed towards research into honeybee losses, and one part of that is specifically about the role of neonicotinoids. However, despite some research having been undertaken about adverse effects of neonicotinoids, many more species and vital functions of ecosystems affected by their use have had little or no public attention at all. They have not been brought together and the connections not made, perhaps not even thought about.
A 2010 review of neonicotinoid pesticide research published by scientists at Exeter University showed that even published field studies were not thorough enough to be able to detect a reduced expected performance in honeybees by between 6 and 20%. James Cresswell explains in this recent paper that a number of studies with bees (a species we might expect to be vulnerable) when exposed to `realistic` levels of imidacloprid failed to show adverse effects; only after meta-analysis of the whole data set did an effect become apparent (Cresswell, 2011).

4.2 Bumblebees

Two early papers looked at the effects of neonicotinoids on bumblebees, Franklin et al (2004) and Morandin and Winston (2003). The Franklin et al (2004) paper looked at clothianidin but they concluded that clothianidin residues in seed-treated canola would not adversely affect bumble bees. The second paper Morandin and Winston (2003) did not look at clothianidin; instead they looked at imidacloprid and concluded "no lethal, sub-lethal colony or individual foraging effect of these novel pesticides were found at residue levels found in the field, suggesting bumble bee colonies will not be harmed by proper use of these pesticides."

It seems it was concluded from these early papers "more or less" that clothianidin and imidacloprid will not adversely affect bumblebees and that was the end of the matter – no further studies were required. In a later paper Scott-Dupree et al (2009) investigated the direct contact toxicity of five technical grade insecticides, imidacloprid, clothianidin, deltamethrin, spinosad, and novaluron currently used, or with potential for use, in canola integrated pest management on bees that may forage in canola. Clothianidin, using technical grade insecticide 99% pure, was more toxic than imidacloprid: when these active ingredients are placed in formulations (seed treatments) and used properly in the field they retain their efficacy in killing the pests but not the pollinators (Cynthia Scott-Dupree, pers.comm.).

However, Tennekes (2010a) is of the view that repeated visits by bees would be much the same as giving them a single dose i.e. the toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time. If that is the case, then repeated exposure does put pollinators at risk. In addition, even if the pollinators are not killed the dosing does affect their behaviour.[11]

Mommaerts et al (2010) found, the experiments in general showed that concentrations that may be considered safe for bumblebees can have a negative influence on their foraging behaviour. Therefore it is recommended that behaviour tests should be included in risk assessment tests for highly toxic pesticides because impairment of the foraging behaviour can result in a decreased pollination, lower reproduction and finally in colony mortality due to a lack of food. Goulson et al (2011) makes the point that at present there is little knowledge as to the impacts of pesticides on bumblebees, although among the non-scientific community this is a topic of great interest and much speculation. In particular, the possible role of neonicotinoids in causing bee mortality has received considerable media attention but few hard data are available. Sub-lethal effects of pesticides, such as impairment of learning ability which might lead to drastic effects at the colony level, have rarely been investigated.

Bumblebee declines are also thought to be primarily driven by the loss of wildflower meadows and hedgerows caused by modern farming practices, with subsequent reductions in the abundance of key pollen and nectar plants such as *Trifolium pratense* Linnaeus (red clover) (Blake et al, 2011) (discussed below and under Plants).

4.3 Butterflies and moths

"Foliage-feeding larvae (caterpillars) of various lepidopterous regularly occur on arable and vegetable crops" (Alford, 2011) and are usually described as defoliating pests and as such will be treated with pesticide. Many larval food plants of butterflies and moths are to be found in field margins and conservation headlands adjacent to cereal and vegetable crops. However, because neonicotinoids have high water solubility (Beketov and Liess, 2008a) they potentially may contaminate the soil in these field margins and headlands following rainfall events and be taken up by larval food plants, thus these marginal plants become as toxic to invertebrates as crops.

Butterfly Conservation warn that most butterflies continue to face serious long-term decline.[12] While loss of habitat has been a significant factor, it appears that with the development of insecticides after Carson there was insufficient study of their wider effects in the field, which were not considered significant. We quote from the Millennium Atlas of Butterflies in Britain and Ireland published in 2001:

> The decline of butterflies is also commonly blamed on the use of pesticides, but there is little evidence for this assertion. Few important butterfly habitats are deliberately sprayed with pesticides, most of which are directed at crop monocultures that contain no larval food plants. The exceptions are field margins which are often the refuge of many wider countryside species in intensively farmed landscapes.

There were two butterfly reports from Butterfly Conservation, in 2001 and 2007, *The State of Britain's Butterflies.* (Fox, 2001, 2007). It is notable that the pesticide issue was not addressed, even though by 2002 neonicotinoids had had widespread use already for nearly ten years. In the earlier 2002 report there is only one passing mention, in the section Declining Common Species, of "management practices, such as the cultivation of former field margins, the use of herbicides and the flailing of hedges each year". Under the section Dramatic Declines in the 2007 report, pesticides were not mentioned at all, in any form.

An earlier (1991) paper by Davis et al had investigated the hazards of insecticides to butterflies of field margins, i.e. prior to imidacloprid use (1992-3). They found it was not generally possible to dissociate the direct effect of insecticides on butterflies from the indirect effects which herbicides may have in eliminating larval food plants, or reducing the abundance of nectar-bearing flowers for adults. They quote Sotherton et al (1985) that the latter is more likely to be responsible for reduced adult butterfly counts in field margins. However there seems not have been any thorough new assessment of the new risks associated with the new insecticides, neonicotinoids.

Conrad et al (2006) identified rapid declines of common, widespread British moths and provide evidence of an insect biodiversity crisis. In a report on moths, *The State of Britain's Larger Moths 2006*, Sir David Attenborough wrote in the foreword: "The results are significant and worrying. A large number of species are in rapid decline" (Fox et al, 2006).

Therefore these insecticides may be having even more significant impacts now than those identified in the paper by Sotherton et al in 1985 and shown as "little evidence" in the Butterfly Atlas in 2001. In addition to the possible nectar- and pollen-poisoning of pollinating butterflies we would point out there is the issue of spray-drift, and the leaching of these water-soluble insecticides into the adjacent field margins, which house and feed butterflies at all life-cycle stages.

4.4 Birds

Although a huge number of papers have been published on the decline of farmland birds and various recommendations made about how to address this situation, none appears to have investigated the newer generation of neonicotinoid pesticides that may be implicated in these declines.

We reviewed papers through a literature search in the ISI Web of Knowledge (up to 28 May 2011) using a combination of search terms including the keywords neonicotinoids, imidacloprid, clothianidin, thiamethoxam, bird, birds, farmland birds and garden birds. Similarly we searched ornithological journals Bird Study, IBIS, and Bird Conservation International back to 1992 (around the time neonicotinoids came on the market) using the same keywords. We found no definitive research paper investigating possible neonicotinoid impacts on wild birds.

As a result of all these investigations, we are concerned to emphasise the impacts on birds (particularly on farmland birds) because it appears that the national bird protection organisations have not grasped that indirect effects of pesticides have been ultimately as fatal as direct effects on birds, who are essential components of agricultural ecosystems, where they "play many roles, including as predators, pollinators, scavengers, seed dispersers, seed predators, and ecosystem engineers" (Sekercioglu, 2006) see also Van der Weijden (2010).

In the UK 80% of the land is farmed and this has the biggest impact on biodiversity. Agricultural change has caused farmland bird population declines and other biodiversity losses in agricultural systems. Wilson et al (1999, quoted in Wilson et al 2009) reviewed impacts of agricultural change on those invertebrate and plant groups that are important components of the diet of 26 seed-eating farmland birds of western Europe (gamebirds, pigeons, larks, corvids, finches, sparrows and buntings). Many of the bird species concerned rely on invertebrates as a protein-rich food source for chicks, and here Wilson et al (1999) found that grasshoppers, sawflies, spiders and leaf beetles, four invertebrate groups that are highly sensitive to insecticide usage, all formed part of the diet of declining bird species. Overall, the review concluded that pesticide usage, intensive cultivations and loss of uncultivated field margin habitats on arable land, coupled with agricultural improvement of grassland through drainage, reseeding and fertilization, were likely to have combined to reduce the availability of key seed and invertebrate food for birds on farmland.

To clarify, Boatman et al (2004) state the need to demonstrate a causal link between pesticides and decline of farmland birds and describe the evidence needed:

(1) an effect of food abundance on breeding performance or survival
(2) an effect of breeding performance or survival on population change
(3) pesticide effects on food resources, sufficient to reduce breeding performance or survival, and hence to affect the rate of population change

“Evidence under all three categories is only available for one species, the grey partridge (*Perdix perdix*), although data showing effects of pesticides on food resources and relationship between food resources and breeding performance are also available for some other species” (Boatman et al 2004; Hart et al 2006)[13]. The Boatman study was undertaken by a team of researchers including members from RSPB, the Central Science Laboratory in York and the Game Conservancy Trust.
Their conclusions are

> “The data presented here, combined with evidence from the literature, demonstrate that indirect effects of pesticides do occur, although, apart from the Grey Partridge, unequivocal evidence is only available for effects of insecticides.”

There is, however, strong evidence for effects of herbicides. We again quote Norman Moore’s comment on herbicides in 1962 “The total ecological change must be immense” (Moore, 1962, cited in Potts, 1986).

4.4.1 Birds and Herbicides

Herbicides such as Glyphosate (e.g. Roundup), developed by the Monsanto Company and introduced to world agriculture in 1974, has become the world’s most important herbicide.[14] It has many strengths, particularly its systemicity and ability to control perennial weeds, which have facilitated its role as an essential tool in modern agriculture (Baylis, 2000). Therefore this particular herbicide has the capacity to kill virtually all arable weeds on which many non-target invertebrates feed and pollinators frequent. This also has implications for many farmland birds and the resulting loss of that invertebrate food supply. Additionally the seeds required for the feeding of young birds, fed as a mash by the parent along with insects (Newton, 1972), and the loss of this seed source to sustain adults through the winter is a factor in the decline of farmland birds. The “reduced availability and abundance of winter seed food has been identified as a key limiting factor of the populations of a suite of declining, resident granivorous farmland bird species in the UK "(Field et al, 2011).

In an exchange of correspondence in Bird Study about overwintered stubble (Potts, 2003, Evans 2004) we note the following comment:
"Granivorous passerines require a seed food source throughout the winter. Historically the abundance of seeds in the seed bank meant that newly tilled fields provided rich pickings for birds (and were often favoured over stubbles, I. Newton pers.comm). Recent changes in crop management have involved large increases in herbicide inputs and much more effective weed control". (Chamberlain et al 2000, Robinson and Sutherland 2002 cited in Evans et al 2004). "This means that both newly tilled fields and stubbles are likely to be relatively less weed rich than in the past" Evans et al, (2004).

In a recent paper McKenzie et al (2011) "Disentangling the effects of fertilisers and pesticides on winter stubble use by farmland birds" the author's results suggests that the main benefit of organic stubble fields for birds is via reduced pesticide inputs. Use of inorganic fertilisers is also beneficial for birds via increased weed seed densities, but to a lesser extent. They conclude that agri-environment policy ought to focus on reducing pesticide use in crops preceding stubble, an option recently included in the Entry Level Stewardship Scheme (J. Vickery, pers.comm.)

We note the papers over the years asking the same questions and drawing the same conclusions that agri-environment schemes are not effective and do not supply the necessary food, especially over winter. These schemes require robust and ecological evaluation to ascertain their effectiveness (Klein and Sutherland, 2003; Whittingham, 2007; Siriwardena et al, 2008; Field et al 2011). It appears that the UK government (Defra) are "myopically convinced that all biodiversity loss is due to habitat change" and disregard the negative effects of pesticides. Modern cereals are treated with a range of herbicides and insecticides, reducing the weed and invertebrate food they have to offer. It is also the case that, due to the increasing demand for and concomitant increase in the price of cereals, more land is ploughed up (and that also means increasing pesticide use) which once might have been set-aside, field margin or beetle bank, which would have provided a wildlife refuge and food supply.

4.4.2 Birds and Ecotoxicology - direct and indirect effects

Many would accept a definition of ecotoxicology given at the beginning of Principles of Ecotoxicology 3rd Edition [Introduction] which is:

> "Ecotoxicology is the study of the harmful effects of chemicals upon ecosystems and includes effects upon individuals as well as effects at the levels of population and above" (Walker et al, 2005).

It follows from this that an indirect effect can be just as important as a direct one. In the end, the population level effect is the most important ecologically. In the case of Boatman's paper, the direct effect of herbicides is upon plants not upon partridges. However, from an ecotoxicological point of view, it is the indirect effect on partridges that is seen as being most important. A similar argument applies to sub-lethal effects versus lethal ones.

It appears that no further work has been carried out, since Boatman. In a RSPB Research Report (RSPB, 2008) the same evidence is repeated “The grey partridge is still the only species for which population level indirect effects of pesticides have been demonstrated”. Lucy Bjork (Senior Agriculture Policy Officer, RSPB) writing in Pesticide News states “The grey partridge *Perdix perdix* remains the species for which the most incontrovertible evidence exists for pesticide-related decline” (Bjork, 2010). In a verbal communication with RSPB in 2011 we were told that evidence of the effects of pesticides is only available for one species, the grey partridge (David Gibbons, RSPB, Head of the Conservation Science Department, pers. comm.)

Additionally Lucy Bjork, in response to an email we sent ”*Pesticides and UK farmland birds*” (11 Feb. 2011), said “I hope you will take from this response and the article in Pesticide News (Bjork, 2010) that we do take seriously the indirect effects of pesticides on our farmland bird populations.”
The habitual response to any question asked of pesticide impacts on farmland birds seems to refer to “the grey partridge study”. However, the grey partridge is just one of many farmland birds; many of the farmland bird species associated with cereal ecosystems have greatly declined and are still declining.

> “The grey partridge in its world wide range down from 120 million individuals to 10 million (Potts, 1986 updated) is merely a well-quantified example; it seems not to be atypical” (Potts, 1991).

We now ask in 2011, why, if RSPB “do take seriously the indirect effects of pesticides on our farmland bird populations”, has no further work been carried out since the Boatman paper of 2004 and the RSPB Research Report of 2008, (and the 2010 article by Bjork in *Pesticide News)*, as farmland bird populations continue to decline?
We refer back to our earlier Section 3.1 and the use of direct and indirect effects.
Pesticides have been shown to depress grey partridge and yellowhammer breeding productivity either from starvation or predation of chicks (Potts, 1986; Hart et al 2006). It has been proposed that hungry broods are at greater risk of predation than broods that are well nourished because hungry chicks attract the attention of predators by begging more loudly and for longer (Haskell, 1994) and because low invertebrate abundance increases the time parents spend away from the nest (Brickle et al 2000). Professor Sharon Strauss has discussed the use of these words, direct, indirect and non-target effects. (Strauss 1991).[15]

While many ecologists consider the effects of pesticides to be indirect, we wish to make the same point as Will Cresswell (Reader, School of Biology, University of St Andrews) when we posed him the following question “Can we argue that these effects are direct in any way, as they basically result in the loss of breeding productivity and in mortality?” He replied:

> “No, I don’t think you can, but you can make the point that calling them indirect effects in no way devalues the strength of the interaction – or implies that pesticides are not the ULTIMATE cause of death – if you stop spraying, you reduce mortality. There is always an issue in ecology about the spatial and temporal scale over which things operate, and in this case the links are short (1 trophic level) and there may be little spatial and temporal separation, so the

use of the term indirect may imply a lack of causation which may then lead to a poorer appreciation by non-scientists of the real cause of the problem" (Will Cresswell pers. comm.)

Dr Potts (1986), who conducted the *Grey Partridge Study*, deduced that the main reason why grey partridges have become scarce in Sussex was the high mortality of the chicks due to the destruction of their food supplies by agricultural pesticides. However this study has not been replicated for other species in the last twenty five years to see if similar studies would come to the same conclusion for other farmland species. Table 2 of the 2008 RSPB Research Report lists the effects of pesticides on ten farmland bird species. On the "strength of evidence" criterion, six are considered to be of "strong" or "strong evidence" of effects, others are likely; but no investigation has been done – the Report states – on almost all of these species, at population level. Only one of the ten, the grey partridge, has had full research attention at population level.

We must remind ourselves that chemical pesticides, whether in use 50 years ago or today, have the same deadly effect on invertebrates, and therefore also all species dependent upon them for survival. We quote, despite its length, the excellent case put by Robert Rudd:

> "The fact seems not widely appreciated that any means of control that even temporarily removes large segments of food populations must inevitably have its consequences on the feeders. Chemical control, particularly, while removing most of a pest population also affects reductions in populations of other species in the area under treatment. Food shortages must follow, which, in extreme, lead to debility, starvation, or emigration. The responses of an individual animal thus affected may be immediate, but not uncommonly they are delayed for considerable periods and expressed in ways that at first sight may not seem associated with the initial cause…..
> "If sufficiently mobile, the feeders will leave a treated area. This movement has been repeatedly observed among insectivorous birds (see Rudd and Genelly, 1956, cited in Rudd, 1964). For example, there was no mortality apparent among birds on Montana range land following a single application of Sevin at one pound per acre for grasshopper control. Yet, within two weeks of spraying, bird counts on the study area dropped from 173 to 30 (De Witt and George, 1960, cited in Rudd, 1964).
> In another instance, again with no visible mortality, all insectivorous birds, except woodpeckers, left within three days when an Illinois bottom land was treated in mid-summer with DDT at one half pound per acre (Couch, 1946, cited in Rudd, 1964).

The point to remember here and expanded below is that crop-dwelling bird communities in one sense are "captives of an ecosystem – species strongly dependent on a single type of food or physical environment" (Rudd, 1964).

When food populations are reduced, due to the use of insecticides removing their invertebrate foods and of herbicides removing their seeds (and the plant foods of invertebrates), and then meet adverse seasonal conditions in combination, wholesale starvation and serious population decline may ensue.

The answer is clear: *no* more research is needed on this topic to show what is going on. The research on the Grey Partridge applies to other “captives” of that particular ecosystem. What is needed is reinstatement of the food supply that crop-dwelling bird species are dependent upon.

However, more research *is* needed on the sub-lethal effects of pesticides on birds, as they may be ecologically important. (Ratcliffe 1963; Moore, 1967; Walker 2003). Seed treatments are widely used for crop protection and present a particular risk to granivorous birds. UK risk assessment for seed treatments has tended to focus on highly granivorous species; however, under some conditions, non-granivorous birds will take seeds. Better data is needed on which species eat the seeds for which pesticide treatments are used (Prosser and Hart, 2005).

Mineau (2011) stresses the importance of non-dietary routes of pesticide exposure in birds. “The origin of the belief that dietary exposure is the only route of exposure worth considering is undoubtedly buried in the organocholine era when many of the tests and risk assessment procedures in use today were first developed. Highly lipophilic insecticides such as DDT were poorly absorbed dermally and, given their bioconcentration and biomagnification potential, emphasis of the dietary exposure route was reasonable. However, even by the early 1970s, there were hard information and data suggesting that routes of exposure with more modern pesticides could be very different.”

4.4.3 Birds and Farmland

In confronting habitat destruction, pesticides and fragmentation, there is an urgent need to understand how organisms cope with an increasing intensity and frequency of stressful events associated with habitat degradation, reduced food abundance, increased competition or predation risk and anthropogenic disturbance(Angelier et al, 2009).

Crop-dwelling bird communities have changed over time and become impoverished, so they move between different habitats to avoid stress. This stress is related to food availability, extreme weather conditions, such as cold winters, or even contamination scenarios (Macdonald and Smith, 1990, and Ferreira et al, 2010). “Birds’ intrinsically high dispersal abilities are insufficient to enable many species to contend with widespread and radical agricultural change” (Macdonald and Smith, 1990).

The interaction between the rate of change of landscape spatial structure and food availability and the rate of change in the dispersal behaviour determines the probability of a species’ regional survival. As long as the rate of change in the dispersal behaviour is greater than the rate of change in the landscape spatial structure, it is possible for the organisms to survive in the changing landscape by moving around in it and integrating the resources over space. However, there will be a possible rate of change in the dispersal behaviour if the landscape structure is changing at a rate higher than this: the organism will be unable to recolonize local extinctions at a sufficient rate and the regional population will be extinct (Fahrig and Merriam, 1994).

Bird declines in Australian agricultural landscapes have occurred decades after most clearing of native vegetation ceased (Saunders, 1989). The delay may partly reflect an extinction debt (i.e. delayed species loss following fragmentation (Tilman et al, 1994).

Winqvist et al (2011) found that simplification of the landscape (we interpret this to be the reduction of the spatial structure) from 20% to 100% arable land, reduced plant species richness by about 16% and cover by 14% in organic fields, and 33% and 5.5% in conventional fields. For birds, landscape simplification reduced species richness and abundance by 34%and 32%in organic fields and by 45.5% and 39%in conventional fields. Rudd (1964) poses the question “does pest control produce biotic changes over large areas? Are we producing “biological deserts”? Yes; pest control, where it assists in the simplifying of habitats, accomplishes these things.

To provide an example of stresses and induced changes:

> “As the original forest was reclaimed by man for settlement and food production, many of the forest bird species became adapted to using the remaining woodland edges, copses and plantations in open country. After the Enclosure Acts of the eighteenth and nineteenth centuries, such bird species found additional habitat in the network of newly created hedgerows, so much so that even contemporary writers remarked on the increase of songbirds in the countryside” (O’Connor and Shrub, 1986).

Perhaps it is too obvious to suggest that if an increase in hedgerows brought an increase in songbirds, then possibly a reduction in total area of hedgerows and other habitat through farmland intensification may bring about a reduction in songbirds!

Chávez-Zichinelli et al (2010), in looking at stress responses of the house sparrow (*Passer domesticus*) to different urban land uses, found that their “results suggest

that the physiological condition of industrial house sparrows could be compromised by differences in the frequency and intensity of the stressor agents faced by the birds in this land use category.” Crop dwelling and farmland bird communities may also be compromised by the various stressor agents e.g. pesticides and habitat degradation in an agricultural land use category.

Two studies, by Doxa et al (2010) and Kragten et al (2010) indicate the benefits of lower-intensity farming:- “*Low-intensity agriculture increases farmland bird abundances in France*” (Doxa et al 2010) and the Kragten et al (2010) study which shows that food abundance for insectivorous breeding farmland birds is higher on organically managed arable farms. It is likely that this will result in higher adult survival rates, breeding success and better fledgling body condition of breeding birds on organic farms. Therefore, lower intensity agriculture and organic farming systems could potentially be beneficial for farmland bird populations.

4.4.4 Habitat Heterogeneity

> “There are no homogeneous environments in nature”. Even a continuously stirred culture of microorganisms is heterogeneous because it has a boundary: the walls of the culture vessel. Some microorganisms will stick to the walls while others remain free in the medium. An environment that is heterogeneous is one made up of different specialised environments. The diversity of species within it may imply that that it contains organisms that match each set of specialised conditions (Begon et al, 1996).

Benton et al (2003) in their paper "*Farmland biodiversity: is habitat heterogeneity the key?*" suggest that habitat heterogeneity is important in maintaining biodiversity. However, they argue that, rather than any particular farming practice causing the current biodiversity decline (such as pesticide use or changes in non-cropped habitat), the multivariate effects of agricultural practices interact very strongly. We argue in this manuscript that insecticides, herbicides and fungicides (collectively pesticides) have singly been the most significant farming practice that has reduced the farmland habitat to one of intolerance for some species of farmland birds and other animal and plant life.

Batary et al (2011) pose the question "Does habitat heterogeneity increase farmland biodiversity?" They caution against generalising against the potential biodiversity benefits of this approach. They argue" that the type and history of agricultural land use must be considered, because introducing habitat heterogeneity can be harmful for specialist (often endangered) species in low-intensity agricultural landscapes.

High-intensity, long-established agricultural landscapes are characterized by substantial inputs of fertilizers and pesticides. Typically, their biodiversity

value has declined sharply since 20th-century agricultural intensification.

In such landscapes, increasing habitat heterogeneity will indeed typically benefit farmland and landscape-wide biodiversity, especially if historical landscape elements

are reinstated (e.g. hedgerows; Benton *et al*. 2003)."

The overuse of pesticides, whether within cropped land or impacting adjacent field margins, hedgerows, conservation headlands, beetle banks through bad farming practice, particularly when spraying, reduces habitat heterogeneity.

Rudd (1964) puts and answers the question "Does pest control produce biotic changes over large areas? Are we producing biological deserts? Yes; pest control, where it assists in simplifying habitats, accomplishes these things."

M. Begon in a pers. comm. and commenting on heterogeneity and homogeneity:

> "I don't really doubt that pesticides have a tendency to make (farmland) habitats more homogeneous, both directly, by eliminating species (and hence habitats) that were not themselves the intended targets of the pesticides, but also perhaps indirectly, in that a habitat subjected to intensification (and hence use of broad spectrum pesticides) is also, within its own terms, likely to be more 'efficient' the more homogeneous it is and will hence be made more homogeneous in parallel with the application of the pesticides. As to whether some species thrive in homogeneous habitats: all other things being equal (important caveat) there will be more species (biodiversity higher) in more heterogeneous habitats (more niches); but also, all other things being equal, there will be more species in larger tracts of habitat (island effects). But the two may be traded off against one another. If you take a fixed area of (farmland) habitat and make it more homogeneous, you will also be increasing the size (amount) of habitat of whatever it is that becomes the dominant habitat. So species that thrive in that habitat may themselves thrive (locally), but quite possibly at the expense of other species, and of biodiversity overall. To some extent, too, it may be a matter of scale. If you narrow the focus to the (now larger) homogeneous patch, some species may do better. But that doesn't mean that they do better overall, much less that biodiversity increases overall. I guess it follows from this - maybe not a conclusion you like - that if

pesticides can be used sparingly and intelligently such that they do not decrease habitat heterogeneity, then they need not reduce biodiversity."

Pickett and Siriwardena in a recent paper "The relationship between multi-scale habitat heterogeneity and farmland bird abundance" (In Press) conclude that their results "highlight a potential role for farmland habitat heterogeneity in determining the abundance of many farmland species, but suggest that population responses to an increase in heterogeneity would not be unanimously positive and would probably have negative impacts on some species, notably those that are already threatened". Examples given are "grey partridge, lapwing, linnet, reed bunting, skylark, turtle dove and yellow wagtail, which were consistently less common in heterogeneous areas, suggesting an avoidance of such habitats. All these species have declined on farmland and featured in the UK government's composite indicator of farmland bird populations that was treated as a proxy for farmland biodiversity in general until 2010".

It is necessary to repeat here our comment in section 4.4.2 "The point to remember here and expanded below is that crop-dwelling bird communities in one sense are "captives of an ecosystem – species strongly dependent on a single type of food or physical environment" (Rudd, 1964)" Therefore, the species named by Pickett and Siriwardena are in fact "captives of an ecosystem" that in fact is not heterogeneous but has been made a biological desert by the use of pesticides and has resulted in the decline of the named species. They prefer the less heterogeneous habitat, but the food sources which would have attracted them there, both insects and seeds, have been eliminated.

4.4.5. Different Approaches and Lessons from Central Europe for general farmland bird ecology.

We refer to section 4.4.6 below and the BBC Panorama Programme (The Truth about Wildlife). In the programme a farmer was featured who uses what was described as "cutting edge technology" to maximise efficiency, whether for crop or wildlife yield. Pesticides and fertilisers are, in usual practice, applied uniformly across a field and can result in over- and under-dosing, which in both cases is inefficient and uneconomical and can be an environmental burden. Precision farming by contrast is an agricultural management system using global navigation satellite systems, geographic information systems, remote sensing, and data management systems for optimizing the use of nutrients, water, seed, pesticides and energy in heterogeneous field situations (Oerke, 2010). The farmer manages 1700ha on 7 farms. As a result of the use of the technology, around 10% of unproductive land on these farms was being used for planting trees, growing pollen and nectar plants and growing 3 types of millet for farmland birds to provide food over the full winter period, alongside the crops in the more productive parts of the land. In order to operate a more heterogeneous and efficient farming system for wildlife the farmer received government grants.

The conservation of remnant vegetation (Bowers, 1999, Manning 2006) and the recognition that all agricultural land cannot be productive is a central issue for the conservation of biodiversity in agricultural landscapes. Remnants may be usefully classified into two types: semi-natural remnants, i.e. biotopes which entirely depend on traditional land use practices (hay meadows, unimproved grassland, woodland pasture; and natural remnants, i.e. biotopes pre-dating human settlement or at least pre-dating agriculture

Whether conventional or organic farming is pursued, a heterogeneous landscape is achievable where fewer pesticides are used (as in conventional farming). Field margins, nectar and pollen crops and other features such as skylark patches are incorporated into the farming system, and remnant vegetation, whether hedgebanks, trees (including foci trees), or unimproved grassland, are safeguarded by agri-environment schemes, such as the planting of unproductive cropland with trees or wildflower strips which provide nectar and pollen, or the planting of winter seed for farmland birds.

We should add that a paper by Krebs et al (1999) (including a member of RSPB staff) even 12 years ago stated the benefits of organic, or more specifically lower intensity, agriculture and remarked that there had up till then been no systematic comparisons of the biodiversity benefits of organic and other 'wildlife friendly' farming methods. Despite this, RSPB, on their own Hope Farm, purchased in 1999, did not use this opportunity to try other methods and have still been pursuing conventional agriculture using pesticides and fertilisers. In our view, they should at least have been doing comparisons of wildlife friendly farming, organic and less intensive methods without the use of pesticides.

In Hungary, populations of birds on farmland are larger and more stable than in the UK; these therefore may offer baseline targets when population restoration programmes are planned in more intensively farmed regions of Europe. Findings correlate with the recent change to generally less intensive agriculture in Hungary (Baldi and Batary, 2011) These conclude that "at the European scale, urgent tasks are to: (1) investigate the relationships between management and bird diversity and density on a much wider geographical scale, (2) evaluate the geographical generality of the existing evidence base (which is mainly based on studies conducted in more intensively farmed regions), and (3) enhance the policy impact of conservation research."

There is a wealth of research papers on the decline of farmland birds. The Journal of Applied Ecology 2000 had a "Special Profile: Birds and Agriculture", in which the Editors' Introduction said:

> "Around 10% of recent papers in the Journal of Applied Ecology have examined interactions between birds and agriculture. This statistic reveals the important role now played by ecologists in assessing the effects of agricultural development world-wide. It also reflects the position of birds as both indicators and targets of agricultural change: their patterns of behaviour, distribution, seasonal phenology and demography track closely onto the spatial and temporal scales of agricultural intensification" (Ormerod & Watkinson, 2000).

There has been a wealth of research papers since then and three recent British Ornithologists' Union Conferences addressing bird conservation in lowland agricultural systems, in 1999, 2004 and 2009. Rather than going through the detail of these, we agree with Jeremy Wilson with Evans and Grice, in a recent Viewpoint paper in *IBIS*, with their question: "Bird conservation and agriculture: a pivotal moment?" (Wilson et al, 2010).

This is indeed a pivotal moment for bird conservation as the agenda shifts towards "ecosystems services" and "food security"…..With the BOU 2012 conference in mind ("Ecosystem services, do we need birds?" See below section 5), how will birds be valued, i.e. "quantified"? What is birds' "service" to the human species? Are we talking birdsong? Or birds who visit the garden to be fed? Or for twitchers' leisure entertainment? A sense of their original place in the food chain seems to be being lost. "As Rachel Carson knew, success will, in part, be measured by birdsong, and failure by its absence" (Wilson et al 2010).

4.4.6. BBC1 Panorama - Britain's Disappearing Wildlife. BBC1 The Truth about Wildlife.

We refer to two BBC television programmes BBC Panorama programme: Britain's Disappearing Wildlife BBC1 (Monday 30 August, 2010 at 2030 BST) and The Truth about Wildlife BBC1 (Monday 30 May, 2011 at 1939 BST).

For the BBC Panorama programme: Britain's Disappearing Wildlife, (BBC 1, Monday 30 August 2010 at 2030 BST), Investment banker Pavan Sukhdev was interviewed. He had been asked by the UN and EU to look at the hard economics of declining wildlife, in particular how costs will rise if species that are so far readily available become hard to find, and to look at biodiversity to find different ways of stopping species decline. He suggested perhaps questions ought to be asked and penalties levied against chemical companies over the costs of their products to biodiversity.

The programme highlighted, in addition to the devastating effects of scallop fishing in the Firth of Clyde (now approaching "a state of ecological meltdown") the state of farming. Farmers control (80%) of the land in the UK; they have been encouraged by the UK government, and latterly the EU, to make farming more productive and self sufficient. The cost of this has been the loss of biodiversity in the farmed landscape. The programme claimed "The UK government is "trusting" and paying farmers to put things right." (restore the lost biodiversity) But many farmers qualify for payments by making few, if any changes, to the way they operate. "A start can be made by actually finding out what farmers want to do on their farms and making sure that if they go into a scheme it will benefit wildlife". The test would be to see the recovery of farmland birds, butterflies and plants etc. Any payments should be linked to results. At the moment 70% of farmers have opted to go into various schemes, but that still leaves 30% not in any scheme. One farmer featured in the programme was receiving £80,000 in subsidies to make his farm more wildlife friendly – he was running 21 environmental projects. He said "I could not do the work without the environmental payments", and even with the payments he has received he says he is subsidising the environmental schemes. His farm has become a "haven for endangered birds", but this is not reflected nationally.

In contrast, in the programme televised on Monday May 30th (2011) at 7.30pm, "The Truth about Wildlife", Chris Packham explored the state of wildlife conservation on farms in England, with more worrying results. He discussed with a small tenant farmer in Somerset why he was ploughing up his wildlife field margins, after ten years in which he received £100,000 in agri-environment grants to preserve these margins. His response was he was trained to grow crops, his business is growing crops and the price of wheat had gone up from £100 a tonne last year to £200 per tonne. He would make approximately £9000 extra from ploughing up the margins and sowing wheat than receiving grants for wildlife. Though he was in the Countryside Stewardship scheme for ten years and received the £100,000 in grants, no-one from Defra or any other organisation came to check that the money had indeed been used for that purpose, or provided any anticipated benefits to invertebrates and farmland birds. *"I have never seen a soul"* was his comment. This example demonstrates wasted money and wasted opportunity; more needs to be done so that such schemes are not approved without sound ecological appraisal and monitoring (Kleijn and Sutherland (2003).

Agri-environment schemes (AES) are paid for by taxpayers and should therefore be used to deliver benefits to the public.[16] No monitoring was done to show what benefits the above example provided to the public in terms of a healthy environment and wildlife, but the farmer appears to have benefitted financially. We ask how many other agri- environment schemes have similarly gone unchecked? For example, at August 2009 there were more than 58,000 AES agreements covering in excess of 6 million hectares (mha) in England. This represents over 66% of English agricultural land – how many of these schemes have been monitored and/or appraised?

In the same programme a representative from the Oxford Ornithological Society said that there were no measurable benefits in terms of bird populations from agri-environment schemes. One of the problems is that agri-environmental schemes provide abundant food from September to December, but after December the seed supply starts to runs out and by March/April there is nothing (see Crick et al, 1991 cited in Buckingham and Peach (2006).

"The birds then move away, die, or a combination of both – but they do not find food." The UK government says, in future, payments MAY be based on actual results. More wildlife, more money! Caroline Spelman, Secretary of State for Environment, Food and Rural Affairs, said there is "an aspiration of 70% of farmers to be in agri-environmental schemes" such as the higher level of Stewardship. This scheme might be the most beneficial as it involves planting crops that attract birds and insects, but who is to undertake the monitoring of the schemes on individual farms?

It would appear that the future lies in the hands of the farmers, but when monies are received for these higher level Stewardship schemes there must be monitoring and inspection to ensure that they are working. The case of the tenant farmer quoted above seems particularly disturbing – as it appears that it was entirely his decision to plough up his margins – without notification or authorisation for this change of use; this action has potentially destroyed any benefit that had accrued for biodiversity in those ten years of publicly funded grants. We have to ask if one of the major reasons for the failure of agri-environment schemes is the lack of monitoring, ecological appraisal and inspection.

4.4.7. Model Farms

Weijden et al (2010) discuss whole farm restoration projects at Colworth Farm owned by Unilever (Pretty et al, 2008) and Hope Farm owned by RSPB. Colworth Farm in Bedfordshire has reduced pesticide use and included spring-sown cereals and set-aside in their crop rotation. A more complex rotation offers farmland birds different resources throughout the year, whereas monocultures have far fewer resources.

Hope Farm is discussed in more detail below, but Weijden et al (2010) state that the farm demonstrated that it is possible to reverse the usually negative correlation between profit and wildlife. By deploying in-field and field margin conservation measures it is possible to increase both yield and bird populations, quite the opposite of the pattern found across Europe as a whole.

Nevertheless, persuading farmers to undertake similar conservation measures, and in some way compensating them for the extra work and loss of yield through agri-environment schemes, while at the same time monitoring and ecologically appraising the schemes, to satisfy taxpayers' money, is not going to be easy. But ultimately the future does lie "in the hands of the farmers" (Chris Packham).

In the television programme discussed above (BBC1The Truth about Wildlife - Chris Packham) a mixed organic farmer from Hampshire had undertaken numerous conservation measures over the years on his farm; for him it is the scale of what we do that will bring results. He poses the question:

> "Is it being done on a big enough scale? and the answer is no. We need hundreds, even thousands of miles, of pollen and nectar strips to make up for this annihilation of the natural habitat that has occurred due to modern intensive agriculture. A radical approach is needed for the care of the countryside in the future. It cannot be regarded as a "smash and grab" facility which you go into and spray here and spread fertiliser there and take out of it what you can. It's more complicated than that". "These are the words of a farmer" (Chris Packham)

The organic farm in Hampshire, and at Colworth and Hope Farms are just examples of what could be achieved but this needs to be repeated on farms over the whole country.

4.4.8. RSPB and Hope Farm

In the Panorama programme, mention was made of Hope Farm in Cambridgeshire which is owned and run by the RSPB and receives a government grant to make the farm more wildlife-friendly (see Appendix 4). Gareth Morgan of RSPB, lauding its success, stated that they "had doubled the number of farmland birds, so they now had twice as many birds as ten years ago and it was done without any impacts on yields, in fact they had maintained and increased yields in crops". Please Note: In looking at the table in Appendix 4 below, one cannot help noting that Mr Morgan's use of the term "doubled" is a little misleading when numbers were either very low or non-existent at the beginning of the project. These low numbers quoted do not add up to sustainable bird populations for the future.

The following statement was made in a Memorandum submitted by RSPB to the Environment, Food and Rural Affairs Committee in 2004: "The RSPB seeks a reduction in the impacts of pesticides because of the long-term risks they pose to birds, other wildlife and the places where they live." http://www.rspb.org.uk/Images/progress_pesticides_tcm9-132859.pdf

However, in viewing Hope Farm's accounts for Harvest 2007 we have seen itemised: Sprays (ie pesticides) £15, 883.13 and Fertiliser £14,610.00, ie in total over £30,000 spent on these two items. As early as 1928 the RSPB had advised against unwise use of toxic chemicals (Bassett, 1980, cited in Smout, (2000). We wonder how many RSPB members today are aware of the scale of expenditure on these two items – rather contradicting RSPB's protestations of the risks of continued use.

It is known that British Beekeepers Association has been receiving money from pesticide manufacturers even when there appears to be mounting evidence of the toxic impacts of pesticides on honeybees. It would be interesting to ascertain if any bird or wildlife charities have been approached by pesticide manufacturers offering monies.

To continue about Hope Farm we quote from RSPB farming website: http://www.rspb.org.uk/ourwork/farming/hopefarm/

"Rather than criticise farmers, the RSPB decided to buy an arable farm to help find ways for modern farming methods and wildlife to co-exist. We were able to do this through the generosity of our members, who donated the necessary funds."

"Hope Farm is a conventional arable farm, and so uses pesticides to control pests – mirroring the decisions of farmers not only in the locality but over 95% of farmers

in the UK. Pesticides are designed to protect crops by killing things that can be harmful to yield or quality: for example, herbicides remove plant pests, insecticides

remove insect pests and fungicides killing fungus infestations. Some weeds are extremely vigorous and need to be controlled, as they out-compete the crop for the resources it needs to grow. Similarly, some insects can significantly damage the crop's development. However, not all weeds and insects are pests, for example, ladybirds are beneficial insects that, if encouraged, can form a natural control for pests like aphids.

"At Hope Farm, we ensure that our contractor uses pesticides in a responsible way. Spraying pesticides only takes place when necessary – namely if pest levels exceed those known to be significantly harmful to the crop. For some pests, the crop can withstand low levels of infestation – making spraying both an unnecessary and a costly activity.

"Insecticide spraying in the summer is one of the most damaging operations any farm can undertake when birds are breeding. At Hope Farm, we have tried to lessen the negative impact of spraying at this time of year by creating a range of insect-rich habitats on the farm. Sometimes the pest levels have been far in excess of that which the crop can withstand, and we have had to spray. We are now looking at varieties of wheat that have naturally higher tolerance to certain pests. We believe that by choosing such varieties we can reduce the probability of having to spray at this important time in the birds' breeding season – and save money too."

We question why RSPB claims to be operating a "conventional arable farm"

a) when it is not owned conventionally but by a charity with charitable aims and funding, and
b) does it follow market trends for increased food production (yields etc.) or do its charitable aims take priority? and
c) when low intensity agriculture (Doxa et al, 2010) or organic (Kragten et al, 2010) would be more appropriate and "increases farmland bird abundances".

RSPB receive, in addition to government subsidies, funds from over 1.3 million members (some of the monies will be used at Hope Farm as they have asked members to donate additionally to this project) and have the authority to actually specify and monitor the contractor (also paid by RSPB) to ensure that field margins and beetle banks etc. are in fact of sufficient size and variety to benefit biodiversity.

Is it credible that a farmer seeking to maintain or increase yields, who is either one of the 30% not in any agri-environment scheme, or one of the 70% who is in a scheme but qualify for payments by making few, if any changes, to the way they operate as described in the Panorama programme, will create environmental features of a size and variety that benefits biodiversity? If the UK government, for example, is willing to pay individual farmers £80-100,000 in subsidies then the taxpayer has every right to be informed if this money is achieving the objectives and in fact whether specific agri-environment schemes adopted by farmers are monitored and/or inspected by Defra.

Richard Benyon, Natural Environment and Fisheries Minister, stated on the Panorama programme that the government had spent billions of £s on agri-environment schemes for farmers to "do good things"; "they have been creating great habitats and had some success". Nevertheless the Farmland Bird Index has shown a drop and "this is worrying". He also confirmed that "if we are giving taxpayers' money to a farmer to do certain things we have to be certain there is an outcome".

In the Editorial of in a recent paper in Journal of Applied Ecology "*The future of agri-environment schemes (AES): biodiversity gains and ecosystem service delivery?,* Whittingham (2011), in referring to a graph, states, "Despite major investments in agri-environment schemes across Europe over the past two decades, populations of farmland birds have continued to decline, albeit at a slower rate than during the 1980s. The graph shows trends of the European farmland bird indicator from1980 to 2008. The trends show changes in composite populations of bird species associated with farmland, forest and other common (generalist species). [Source: EBCC/RSPB/BirdLife International/Statistics Netherlands]. The ultimate efficacy of AESs is often judged by trends such as this but tests for the effectiveness of management are often carried out at much smaller scales."

The repeated and widespread application of pesticides and fertilisers is changing the whole nature of the medium of the soil, the living on which all species depend.

We refer again to the "pesticide treadmill" discussed above in section 3.9 (Van Den Bosch, 1978 and 1989). Perfecto et al (2009) puts it like this:

> "A resurgent pest suggests to the farmer that more pesticide is needed since the problem is worse. Because of resistance, the pesticide is no longer as potent as it once was, suggesting to the farmer that more pesticide or stronger pesticide is needed, and the new pests that mysteriously appear suggest once again more pesticide is needed. The more pesticide you use, the more you need – hence the name the "pesticide treadmill."

It would appear that RSPB are making the same mistakes as the modern farming industry in the use of pesticides and fertilisers. It would have been more appropriate for RSPB to instigate a natural control of pest species, and to look at application of organic methods or similar of nourishing the crops. A conceptual framework for comparing land use and trade-offs of ecosystem services is suggested by the paper in *Science*, "Global Consequences of Land Use" by Foley et al (2005). They state that

> "Natural ecosystems are able to support many ecosystem services at high levels, but not food production. Intensively managed cropland is able to produce food in abundance (at least in the short run), at the cost of diminishing other ecosystem services. However, a middle ground—a cropland that is explicitly managed to maintain other ecosystem services—may be able to support a broader portfolio of ecosystem services".

An interesting historical observation is made by Jones et al (2005) in the discussion section of their paper "*In contrast to studies of farmland bird diversity on larger industrialized farms* (Chamberlain & Vickery, 2002; Murphy, 2003; Peterjohn, 2003), "we found that farmlands in north-central Florida support a large proportion of bird species native to the region. Moreover, nearly all birds we watched foraging were not being destructive to crops but were eating invertebrates that eat crop plants. These patterns are reminiscent of findings by early farmland bird researchers, before the rise of industrial agriculture, when native birds interacted in primarily positive ways with farming systems" (Forbush, 1907; Weed and Dearborn, 1935).

RSPB, a bird protection charity, calls Hope Farm "a conventional arable farm", and doesn't "want to criticise farmers". Why not? Have RSPB become complacent?

For many farmland birds to survive and thrive, they need a year-round supply of insects and seeds in appropriate seasons. Insecticides remove the insects and herbicides eliminate key weed species which support the insect populations and provide seed. As we quoted on page 4 above: "the indirect effect can be many times stronger than the direct effect" (Sharon Strauss and Judea Pearl, pers.comm).

"The answer" for RSPB "is *natural control*, the combination of physical and biological factors in the environment that maintains all species populations within characteristic limits. In other words, there *is* a balance of nature going on around us all the time and the most broadly affected group of organisms are the insects and their cousins the mites, the earth's most diverse bundle of species….What is most amazing about this natural restraint on insect populations is that much if not most of it results from the impact of bug upon bug. In other words the insects are their own worst enemies. (Van den Bosch, 1989)

4.5 **Bats**

Insects are the principal food for many animals, including bats (Chiroptera), and all species of bats in the United Kingdom feed over agricultural habitats. Bat populations are declining throughout Europe, probably in part as a result of agricultural intensification. The intensification of agriculture has been possible through increased mechanization and use of synthetic chemical fertilizers and pesticides (agrochemicals). However, this increased production has been accomplished at the expense of farmland habitat diversity and farmland biodiversity. (O'Connor & Shrub 1986 cited in Wickramasinghe et al, 2003).

Nocturnal and crepuscular aerial insect abundance and species richness were significantly higher on organic farms than on conventional farms. The primary reason for this difference is likely the use of agrochemicals on conventional farms. Pesticides reduce insect numbers of both target and non-target species, even in unsprayed headlands as a result of spray drift. (Wickramasinghe et al, 2004).

4.6 Plants (Weeds)

“Chemical weed control has become so successful that, for the last three decades, fewer weed scientists have been trained; industry severely curtailed the quest for new herbicide targets of action due to the success of herbicides and herbicide-resistant crops.” (Gressel, 2011a). Little wonder that weed species (usually many wildflower species) are becoming rare, and species dependent upon them, birds, butterflies etc., are also declining!

Since the early 20th century, the diversity and abundance of the arable weed flora across Europe has declined due to the intensification of crop production systems (Gibson et al, 2007, cited in Hawes et al, 2010). In their own 2010 study, Hawes et al claimed “increasing the diversity of cropping practices between fields may offer a complementary approach to reducing agrochemical inputs for enhancing arable biodiversity across landscapes”.

Plants are a crucial part of the wildlife mix. Potts et al recently investigated ”Long-term changes in the flora of the cereal ecosystem on the Sussex Downs, England, focusing on the years 1968–2005” (Potts, Ewald, and Aebischer, 2010). The study emphasised the opportunities that exist to restore the eco-system flora in at least some landscapes by restricting the use of herbicides in the headlands of cereal crops. “While identifying that the soil seed bank remains sufficient to enable a rapid restoration of the pre-herbicide flora where needed for wildlife conservation purposes….the means to do this are available through UK’s Agri-environment ‘in-field measures’, but these are very unpopular with farmers”. Walker et al (2007) found that Agri-Environment schemes can be effective in conserving arable plants, including rare species, across a variety of landscape types.

Potts, in describing the” Environmental and ecological importance of cereal fields” in his contribution to *The Ecology of Temperate Cereal Fields*, stated that he believed “the main problem is that at present too few perceive the cereal ecosystem as an ecosystem as opposed to an artificial system. If this could be overcome, extensification would be given greater priority and a richer environment would appear in the wider countryside” (Potts, 1991 in Firbank et al, 1991).

Storkey and Westbury (2007) discuss “weeds” and whether planned measures to conserve them for wildlife will be sufficient in volume. “As a result of the recent intensification of crop production, the abundance and diversity of UK arable weeds adapted to cultivated land have declined, with an associated reduction in farmland birds. A number of questions need to be addressed when considering how these declines can be reversed”. They conclude:

> “Firstly, if vegetation cover is only established on uncropped areas, such as field margins or set-aside, will this be sufficient to reverse the decline in the flora and fauna associated with farmland? This is the preferred option for the majority of farmers who remain viscerally opposed to managing weeds in crops“.

NB: Set-aside was abolished in 2007, and replaced by a reduced industry-led voluntary scheme, but some farmers, up to 30%, (as reported above) have not taken them up. (BBC Panorama 2010)

4.7 Orchards

Over the past half century or so the land area occupied by orchards in the UK has more than halved. However, orchards are home to a rich diversity of wildlife, associated with not only fruit trees and the overall ground flora but also with windbreaks and surrounding hedges. The guild of temporary or more permanent inhabitants include a wide range of invertebrates. Admittedly some of these might be pests. However, at the other extreme there are likely to be beneficial species acting as pollinators or as natural enemies of pests. Insect pollination in orchards, whether by honeybees (perhaps temporarily imported by man) or by naturally occurring pollinators such as bumblebees, is a key component of the fruit production cycle. (Alford, 2011).

Mols and Visser (2002 and 2007) investigated alternative ways to control caterpillar pests and reduce the use of pesticides in apple orchards in the interest of the environment, farmers and the public. The studies looked at the potential contribution birds can make to pest control. These studies considered whether great tits (*Parus major*) can reduce caterpillar numbers and fruit damage by caterpillars, and increase biological yield, in an experimental orchard of apple trees with high caterpillar numbers. They conclude "With the tightening of regulations on the use of pesticides, resistance of harmful insects to pesticides and the adverse public attitudes to pesticides, great tits should be encouraged as a pest control agent for caterpillars in orchards". Mols and Visser (2002)

Bouvier et al (2011) in a recent paper "Apple Orchard Pest Control Strategies Affect Bird Communities In South-eastern France" concluded that "The results of the present study, by pointing out the positive effects of reduced synthetic chemical pesticide use on bird abundance in organic and IPM orchards, favour lower pesticide inputs if we are to promote biodiversity-based control of pests."

4.8 Gardens and Greenhouses

While most pesticides are used in the farmed landscape many domestic gardening products on sale in hardware stores and garden centres also contain these chemicals (neonicotinoids). The Soil Association has identified some of the commonest products containing these pesticides, for which see Appendix 2 below.

There have been well documented declines of bees, butterflies and invertebrates and birds in domestic gardens. A particular focus has been the house sparrow (*Passer domesticus*). Summers-Smith (1999) concluded that the most important reason for the decline in rural areas in the south-east and the Midlands is a decrease in the availability of the animal food that is necessary for rearing nestlings. Decline in large cities also could be caused by reduction in the numbers of arthropods, and another suggestion is that atmospheric pollution from vehicle exhausts is a second significant factor. (Denis Summers-Smith pers. comm.)
The situation of the house sparrow remained much the same in later studies (De Laet and Summers-Smith (2007). The decline of urban house sparrows in NW Europe started about 1990. ….this date has never been challenged and remains today the only estimate of the onset of the urban house sparrow decline in NW Europe (Summers-Smith, 2003).

Imidacloprid, one of the family of neonicotinoids, was first synthesized in its active form by Bayer HealthCare in Japan in 1986. It was developed for control of a variety of insects for both agricultural and veterinary purposes. Assuming it came onto the mass market in the early 1990's, it could be suggested that there might be a link with decline of sparrows, given that many householders destroy invertebrates on their plants, thus eliminating a vital food source for nestling sparrows.

http://www.animalhealth.bayerhealthcare.com/4894.0.html

Cloyda and Bethkeb (2011) warn of the "Impact of neonicotinoid insecticides on natural enemies in greenhouse and interiorscape environments". "The neonicotinoid insecticides imidacloprid, acetamiprid, dinotefuran, thiamethoxam and clothianidin are commonly used in greenhouses and/or interiorscapes (i.e. plant interiorscapes and conservatories) to manage a wide range of plant-feeding insects such as aphids, mealy bugs and whiteflies. However, these systemic insecticides may also be harmful to natural enemies, including predators and parasitoids. Predatory insects and mites may be adversely affected by neonicotinoid systemic insecticides when they: (1) feed on pollen, nectar or plant tissue contaminated with the active ingredient; (2) consume the active ingredient of neonicotinoid insecticides while ingesting plant fluids; (3) feed on hosts (prey) that have consumed leaves contaminated with the active ingredient" (see section below on Alternatives to Management by Pesticides).

4.9 Household Chemicals

Interest and concern about the human health and environmental impacts of chemicals in personal care products and other consumer products that are released to the environment through wastewater treatment systems are a continuing issue.
Examples include detergents and other cleaning agents, solvents, household pesticides, fragrances, pharmaceuticals, biocides, and antimicrobials such as triclosan. Triclosan is contained in numerous consumer products and has been found worldwide in municipal and industrial wastewater (Mackay and Barnthouse, 2010). Although the treatment efficiency of Waste Water Treatment Plant effluents is high, many of the residual bio-solids are applied to agricultural land and the ecological risks to soil microorganisms and invertebrates, plants, mammals, and birds must be considered.

4.10 Potential impacts on mammals, including humans

In this manuscript we have not looked in any detail at some other species that are dependent on invertebrates, seeds and other plant matter. These species include mammals such as water vole, brown hare, harvest mouse and additionally reptiles and amphibians, fish, etc. Nevertheless it is quite easy to find papers such as the one by Ade et al (2010) whose study suggests that Cricket Frogs may be especially sensitive to the insecticide imidacloprid, as well as fish predators, and that these factors could contribute to their population declines.
Morris and Thompson (2011) point out that European legislation requires that plant protection products have no unacceptable effects on the environment, particularly non-target species. The European Food Standards Agency (EFSA) Birds and Mammals Guidance Document (EFSA, 2009) highlights that de-husking, the

mechanical removal of the outer casing of seeds, may decrease the risk posed to small mammals from exposure to pesticide-treated seeds. However, de-husking is likely to vary by species and crop. Therefore, standardized methods with wild species are required to ensure comparability, and further consideration should be given to the intake of residues during the de-husking process, which has received little attention to date.

According to the World Health Organisation, some three million people a year suffer from severe pesticide poisoning. The chemical in biocides are now found at unacceptable levels in the bodies of people worldwide, and can cause cancer, birth defects, and damage to the nervous system (Dilworth, 2010, page 372)

In a systematic review (Shirangi et al, 2010) that evaluated the current epidemiological evidence on the association between living near agricultural pesticide applications and adverse reproductive outcomes, including congenital malformations, stillbirth, intrauterine growth retardation (IUGR), low birth weight, pre-term birth and miscarriage, the evidence suggested an association for congenital malformations, but because of methodological limitations, such as poor exposure measurement and potentially inadequate control of confounding, a firm conclusion remains beyond reach. For the other outcomes (stillbirth, IUGR, low birth weight, pre-term birth and miscarriage) the evidence for any associations was equivocal at best, but some leads warrant further investigation. Improved exposure assessment methods are needed to obtain a more reliable assessment of any risks.

In a recent paper by Duzguner and Erdogan (2010) their results indicate that "imidacloprid, which has been widely used for flea and crop insect control, may cause acute health damage in non-target organisms leading to oxidative stress and inflammation. Therefore further investigations should be performed on this insecticide to assess its possible risk to humans and other mammalian species."
Another study by Najafi et al (2010) on mature male rats after exposure with imidacloprid Insecticide stated that "Clinical observations demonstrated decreased movement, staggering gait, occasional trembling, diarrhoea and spasms in the test groups".

To sum up, there are potential risks to operators using insecticides, to those living or working near where applications are being made, to those who are manufacturing the chemicals: all need further investigation and/or research.

5. Ecosystem Services (ES)

A calling card for much of the modern environmental movement has been "ecosystem services", that not so subtle suggestion that ecosystems in all there complexity serve humanity and that disturbing them, or implicitly, simplifying them, may result in the loss of those services (Vandermeer, 2011). Thus services such as pollination, maintenance of soil quality, nutrient recycling and many others are significant concerns in agriculture but are commonly taken for granted in more natural ecosystems. Invertebrates play significant roles in many ecosystems services, but quantifying and defining those roles is often difficult and has usually not been attempted (New, 2005). In agricultural ecosystems it has become the norm to protect crops with pesticides rather than creating habitat and refuges for natural enemies of pests and fails to recognise that soil biodiversity per se can be a significant and positive resource for farmers. Although there is generally a good understanding about the key pests and natural enemies in crops, there is often surprisingly little known about ecology of these organisms and the habitats that support them. Even when this information is available it is generally not incorporated in pest management, although there is momentum growing for more ecologically based, scale-specific IPM (Bianchi et al, 2010). We note the number of research papers appearing on ES relating to the recognition of "what the natural world supplies for free" e.g. pest suppression (Bianchi et al, 2010) bats (Kunz et al, 2011), European pollinators (Potts et al, 2011) and birds (Whelan et al, 2008 and Sekercioglu, 2006).

5.1 Ecosystem services from an ornithological perspective?

"Seafood, new pharmaceuticals, timber, soil fertility, pest control, waste detoxification and flood control are just a few examples *(and we add pollination)* of what is disappearing with the destruction of natural habitat throughout the world." (Daily, 1997). In the following section we look at the role birds play as part of *Nature's Services*.

Interest in the economic role of birds as pest control agents receded as agriculture became more mechanistic, large scale, and dependent upon the rapidly growing availability of effective pesticides (Whelan et al 2008). The loss of their "economic value", and the declines of bird populations described earlier in this manuscript, have prompted the need for a re-evaluation of their function, and that of biodiversity generally; the many other contributions of birds to human living have been taken for granted, and have not until now needed to be articulated in policy. Recently, it seems as a move towards a revaluing of biodiversity, the concept of Ecosystems Services has emerged and is now widely being brought into planning and policy. "Ecosystem Services" seem to denote natural processes that benefit humans – seen from the human point of view. It is suggested that birds contribute the four types of services recognized by the UN Millennium Ecosystem Assessment—provisioning, regulating, cultural, and supporting services (Whelan et al 2008).

The British Ornithological Union, in its preparation for its conference of 2012, "*Ecosystem services, do we need birds?"*, asks "What kind of value birds would be allowed to have in the 'The United Nations Millennium Ecosystem Assessment', and goes on to say "This assessment of ecosystems has led to a burgeoning interest in the economic benefits of nature and represents a paradigm shift for conservation. Humans benefit from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and can be grouped into four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits.

> "Birds play many roles within ecosystems, including as predators, pollinators, scavengers, seed dispersers and predators, and ecosystem engineers. In terms of cultural services, birds provide enjoyment to millions, through recreation and sport, can be 'flagship' species for conservation and are used as measures for the quality of human life. However, quantifying the ecosystem services provided by birds is a significant challenge and the underpinning evidence on which to base policy is still lacking. Moreover, valuing birds in this way potentially represents a move away from traditional species conservation, with profound implications for setting conservation targets and practical management."[17]

The combination of biodiversity goals with broader ecosystem services has been widely advocated. The question must be asked" Can "ecosystem services" be integrated with conservation? (Rhymer et al, 2010, and Bradbury et al, 2010).

One of the criticisms of the ecosystem services approach, and the emphasis on ecosystem services that benefit society, is that it fails to accommodate the intrinsic value of wildlife and its role in the functioning of ecosystems independently of any human benefit (Redford and Adams, 2009 quoted in Stoate, 2011). Redford and Adams (2009) outline seven problems with ecosystem services and while saying "ecosystem services are extremely important they need to be drawn into conservation strategies with great care".

Again we ask: Can biodiversity, indeed can birds themselves, be "quantified" in any meaningful sense? Can quality of life be measured? With the shift in policy described above what of value could also be lost?

While it is not in the remit of this manuscript to stray beyond pesticides, mention should be made of the wider debate about the human dominance of the planet and of the predominance of rationalist, functionalist thinking, using the Earth as a free "supply house and sewer" (Macy and Brown, 1998), and the need for the change to ways of thinking and acting which gives respect and value to the "more-than-human" world, and humans as one species among many (Abram, 1996, and Harding, 2006).

In a recent book review in the journal IBIS we think Steve Redpath sums up our feelings "We live in a time when concepts of ecosystem services dominate academic thinking and guide conservation policy. A lot of thought is given to the services that the uplands provide for society, with an emphasis on attempts to quantify their monetary value. The reviewed book "*In Search of Harriers*" is a stark reminder that it is often the nonmonetary value of biodiversity that provides compelling arguments for conservation." (Redpath, 2011)

We also note an early paper by Pimm (1997) "The value of everything"… "Economists and ecologists have joined forces to estimate the annual value of the services that Earth's ecosystems provide. Most services lie outside the market and are hard to calculate, yet minimum estimates equal or exceed global gross national product" (Pimm, 1997). Pimm asks "Aren't there overarching moral issues in placing monetary values on a sustainable environment for future generations?

5.2 What the natural world supplies free….?

For further understanding of this subject and ecosystem services we recommend consulting these books.

Nature's Services Societal Dependence on Natural Ecosystems, (Daily, G.C, ed., 1997)

Nature's Matrix; Linking Agriculture, Conservation and Food Sovereignty, (Perfecto et al, 2009).

6. Alternatives to management by pesticides

So if pesticides are not the Hero after all, the solution to many of the farmer's troubles, what else is there?

Integrated Pest Management (IPM) has been endorsed by UNCED (1992) as part of Section 14 ("promoting sustainable agriculture and rural development") as "the best option for the future, as it guarantees yields, reduces costs, is environmentally friendly and contributes to the sustainability of agriculture" (UNCED, 1992, paragraph 14.74).[18] IPM may include pesticides (with reduced use) and biocontrol, ie arthropod predators and fungal species, to control pest species.

However, practitioners of IPM must be aware of the potential harmful effects of insecticides on these arthropods, which may eliminate beneficial predatory invertebrates of pest species (Winston, 1999). A comparison of methods and costs, of using biologically based alternatives to replace some pesticide use, is covered in the 1993 book "*The Pesticide Question*" by Pimentel and Lehman.

In a recent study, Geiger et al (2010) raise questions of landscape scale and mobility of species:

> "...both organic farms which apply only those pesticides considered harmless to the environment, and agri-environment schemes, had positive effects on plant and carabid diversity, but did not show the expected positive effects on bird species diversity. Possible explanation for the lack of such positive effects is the large spatial scale of the pollution associated with pesticide use across Europe, which inevitably leads to the negative effect of pesticides – even in areas where the application of these substances has been reduced or terminated. Such large-scale effects will be especially relevant for taxa that utilise large areas such as birds, mammals, butterflies and bees."

Already mentioned above (p16) are two studies, by Doxa et al (2010) and Kragten et al (2010) which indicate the benefits of lower-intensity farming: that food abundance for insectivorous breeding farmland birds is higher on organically managed arable farms, with results of higher adult survival rates, breeding success and better fledgling body condition of breeding birds.

7. Licensing and Scientific Study – Shortcomings and Omissions

In European countries the initial licensing is done at European Union level by way of a Draft Assessment Report (DAR); but although the basic research for it is usually done by independent scientists, the organisation of the report – remarkably, you may think – is carried out by the manufacturer. So the DAR for the commonest neonicotinoid, imidacloprid, was put together by Bayer, the manufacturer of imidacloprid, and which makes many millions of pounds from it every year. Bayer's report found no reason why it should not be approved.

In the USA the Environmental Protection Agency has been accused of covering up a "critically flawed" scientific study which suggests that "there may be imminent hazards to honeybees posed by continued use of clothianidin, the pesticide in question".[19] The organisations *Pesticide Action Network* and *Beyond Pesticides* joined beekeepers from around the USA in calling on the EPA to pull the neonicotinoid (one of Bayer Crop Science's top-selling pesticides) clothianidin, which is linked with Colony Collapse Disorder (CCD), off the market immediately.[20] [21] Of 94 pesticide active ingredients released since 1997, 70% have been given conditional registrations, with unanswered questions of unknown magnitude.

7.1 Defra Consultation, UK[22]

In February 2010 there was a consultation on the implementation of the new EU Directive on the Sustainable Use of Pesticides (SUD) (designed to reduce the risk of harm to humans and the environment from the use of pesticides). Notably, the British Medical Association was amongst those recommending that it should be a requirement to provide advance notice of spraying events, in order to protect vulnerable individuals, such as those with respiratory problems. In a disappointing reply to the consultation, Defra failed to address health and environmental concerns and committed the government to very little beyond some minor changes to meet new requirements. Defra claimed no compelling evidence was provided in the responses to justify further extending existing regulations and voluntary controls.[23] Further consultation was to take place the next summer to ensure that new legislation is in place by November 2011.

Lord Henley, Farming minister, said:

> "We have to protect the public and the environment from harm, and we'll do so by following sound scientific and other robust evidence. By making a small number of changes to our existing approach, we can continue to help feed a growing global population with high-quality food that's affordable, while minimizing the risks of using pesticides."

We put the question:

Is it really the intention of the government and/or Defra to "feed a growing global population", given the limited land use availability and population of the crowded UK, and at the same time maintain the ecological diversity of the landscape?

The work by Crane et al, commissioned by Defra, which we mentioned on page 1, identifying the many public concerns about pesticides, was “greeted with a thunderous silence” (M. Crane pers.comm.)

We question this lack of response from Defra and why a newly released Government report claims that field studies show that neonicotinoid pesticides have "no gross effects" on honeybees based on unpublished field studies that have not been subject to open examination.

http://www.buglife.org.uk/Resources/Buglife/Government%20review%20of%20honeybee%20and%20neonicotinoid%20pesticides%20released.pdf

7.2 Pesticide Action Network UK (PAN UK)

PAN UK, the coordinated pesticide pressure group, has been calling on the UK government to adopt a range of measures under the SUD that would see the UK at the forefront of pesticide regulation in Europe.[24] In the International Year of Biodiversity 2010, Pesticide News (PAN UK), 88, June 2010 declared “Pesticides reduce biodiversity” and gave in support of the article a list of 91 references, many of them peer reviewed. The UK has missed two international targets both aimed at reducing species declines. Every other signatory country, 191 in total, also missed the targets.

PAN requests:

- A targeted-use reduction of pesticides deemed to be toxic to bees and other pollinator species
- A prohibition on the use of pesticides in areas frequented by vulnerable groups such as parks, hospitals and school
- Mandatory prior notification of spraying events.[25]

7.3 Climate Change (Monsanto Planning Ahead)

> “Monsanto does not have its own climate scientists, so the Panel established contact with external experts and collected extensive information on the development of this area of science, and the origins of the theory of man-made global warming. The Panel found unequivocal and convincing data that temperatures are now
>
> increasing and precipitation patterns are changing in a manner largely consistent with that theory (Gustafson, 2011).

Clearly, crop protection will become increasingly difficult as higher-yielding varieties present a larger and more tempting target to all pests, and the pests themselves extend their ranges poleward and into other new geographies owing to reduced winter kill and longer growing seasons. Fortunately, good progress on enhancing crop protection technology to meet these challenges is already being made, but the scope of this climatic provocation is such that complacency is not an option. Increased investment into new technologies and adoption of new agricultural practices with improved adaptive and mitigation potential are both essential” (Gustafson 2011).

It would appear that the strategy of dealing with climate change from this particular chemical manufacturer is “more of the same”.

7.4 For political issues see Appendix 3.

8. The Naturalists Are Dying Off – Specialisms and the Whole Picture

From the researches we have done and our observations, we have come to believe that the discussion of pesticides and their impacts on wildlife and the environment has lost impetus since the banning of DDT in the 1970s and the introduction of neonicotinoids in the early 1990s, following the published works by Carson, Rudd, Moore, Mellanby, Egler, Van den Bosch and Sheail. Many of these early authors were trained biologists, entomologists, ecologists and naturalists.

Even in 1996, Reed Noss (1996) called on "all biologists – ecologists, evolutionary biologists, botanists, zoologists, population geneticists, taxonomists, systematists and others - to join together in resisting the trend to indoor biology". He continues "Nothing will destroy the science and the mission of conservation biology faster than a generation or two of biologists raised on dead facts and technology and lacking direct personal experience with Nature. In private conversation virtually every biologist I speak with is seriously concerned with the death of natural history".

From our own academic experience we note with regret the loss of the academic tutor and naturalist either through retirement or death, who has been replaced by molecular scientists and researchers in very specialised subject areas who may have too many responsibilities and commitments and little to spend time in the field. We had the following comment from an academic reviewer of our manuscript "as a naturalist in a sea of molecular biologists I note also the passing of diversity in biological academia."

In fact many field trips for students are less frequently held on Health and Safety grounds, so that practical experience of natural history for students is sadly lacking. In a gathering of nearly 70 scientific participants of the Advanced Study Institute on Pesticides in the Environment at Monks Wood Experimental Station 1-14 July 1965 (Moore, 1966) we can see from the group photograph a classic collection of scientists and field naturalists e.g. N.W. Moore, D.A. Ratcliffe, K. Mellanby, B.N.K. Davis, M.D. Hooper from the UK and others from Europe and America. We consider that if a similar meeting held today would lack such a notable collection of participants knowledgeable of science and natural history. The naturalists are literally dying off. Monks Wood itself has "died off" too – the government closed this important research station at the end of 2008.

Why does this matter? Why are naturalists important? Why are they needed? They are needed because they are the people "in the field". With their combination of practical experience and trained observation skills with a broad theoretical knowledge of the ecology of the planet, they are well placed to see both what is happening, and what has happened and what perhaps should happen.

The only recent published work looking at the impact of pesticides on wildlife and the environment is that of Henk Tennekes (2010b) who, not a biologist, is a toxicologist.

"One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise." (Leopold, 1968).

The chemical industry has powerful influence and seems repeatedly to have sought to discredit authors who criticise their pesticide products. It is possible that perhaps many potential authors have been largely scared off publication as the pesticide companies have become more powerful. This is well-described in Egler, 1966, and Martin, 1996. Many dissident experts are subject to dismissal, transfer and blocking of appointments, research grants, and publications (Martin, 1996)

Robert Rudd's book *Pesticides and the Living Landscape* (see Recommended Reading), published in 1964, went through a lengthy and exhaustive review process, with 18 reviewers, at The University of Wisconsin, and was very favourably received (Martin, 1996). The book was largely ignored by the pesticide industry, as, because of its competence, "they could find no grounds to attack him". As one reviewer of his book said "If we further delay adopting Rudd's approach to pesticides and continue in a policy of biological brinkmanship, we may well find that persistent pesticides will become one of the biggest outrages ever perpetuated on our planet" (Collins, 1964).

9. **“Broadening the Ecology in Ecology Risk Assessment”** (Wenning, 2011)

> “Commenting on the evolution of ecotoxicology from the 1970 s, Van den Brink (2008, cited in Wenning 2011) observed that only a limited amount of ecological theory has become integrated into the field of ecotoxicology and ecological risk assessment (ERA). Ecotoxicology, to date, has focused on investigating the impacts of chemicals on individual organisms, rather than populations, communities, or ecosystems. Typical ecotoxicity experiments, which employ standard laboratory conditions to test a chemical’s effects on individuals of a standard test species, have yielded considerable volumes of data that are used in ERAs to estimate environmental consequences of chemical release into the environment. How these experiments inform the understanding of ecosystem-level impacts is not as well understood. As a result, Van den Brink (2008) argued for the need to correct the ecological deficiencies in current ERA practices, and to encourage ERA frameworks that integrate some level of ecology and science-based, ecosystem-level risk assessment methodologies into decision-making.”

ittbrenner et al (In Press) warn of “the use of only one or a few species—representing an entire taxon—in ecotoxicological standard tests poses risk of underestimating the impact of toxicants on the environment. In the case of testing only one species, an increase of safety factors should be considered.”

10. Recommended Reading:

The Bird of Time -The science and politics of nature conservation by N. W.Moore, Cambridge University Press.

Although published in 1987, this text is still relevant today.

Pesticides and the Living Landscape, R.L. Rudd, Faber and Faber. 1964.

Egler (1966) argued vehemently that Carson (*Silent Spring*) had been assailed unfairly on non-scientific grounds. He cited the critics' muted response to Rudd's book, who had drawn the same conclusions as Carson in his *Pesticides and the Living Landscape*, written for a scientific audience: "It is interesting—and damning—that the opposition, unable to attack Rudd on grounds of his professional status, his style of writing and the public for which he aimed, have largely chosen to ignore him".

Farmland birds across the world. W. van der Weijden , et al, eds, (2010), Lynx Edicions, Barcelona.

11. The spreading of knowledge – who knows what?

One professor specialising in birds said to us recently: “Neonicotinoids: what are they? I have never heard of them and neither has anyone else I know!”

The role of neonicotinoids has received considerable media attention because of the debated effect on honeybees, but research about their negative effects on non-target invertebrates, birds and the soil and aquatic environments is either lacking or has taken place in separate disciplines; little “hard” data is available or accessible or connected up to build a whole picture of the effects. We have found an astonishing lack of awareness, not only of their effects but even of their very existence.

At present there is indeed evidence that neonicotinoids do have a negative effect on biodiversity, based on the research papers we quote.

However, “existing knowledge is not very accessible. Most journals are subscriber only. Even with access, interpreting results can be tricky for people not familiar with the latest modelling and statistical techniques. There is not enough communication between research scientists and practising conservationists” (Dicks and Sutherland, 2011). There is relevant evidence in this manuscript, and, secondly, we have made it accessible, so we hope it can be applied to future decision-making.

One of the most significant things we have remarked on is the lack of availability of knowledge. A critical assessment is given in the paper by Goulson et al (2011) A “Practitioner’s Perspective”

> “..Publishing a paper, no matter how good the science may be, does not in itself improve the fortunes of a single bumblebee. It is only when the research reaches the right audiences and is translated into practical action that it makes any difference. Very few farmers, gardeners, politicians or nature reserve wardens sit down of an evening to read a scientific journal” (we interpret this to be slightly patronising), “nor should we expect them to. If they did, they might struggle to make sense of most of it. Academics must take some of the blame for this situation; many researchers make little effort to communicate their work beyond the traditional use of scientific journals, publications which are all but incomprehensible to the layman. This in turn is largely because the traditional criteria used for judging academic success pay little attention to the impact of the research. In some areas of science the breakdown of communication between scientists and the public may not be too disastrous, but in conservation this matters profoundly, because, if conservation research is not communicated to those who might implement it, then the research effort (and funds) were wasted. Yet there remains a yawning gulf between the research consensus and practical on-the-ground habitat management, and it is not clear whose job it is to bridge this gap. This applies both at the level of rare species conservation (arguably the territory of conservation NGOs) and at the more basic level of maintaining healthy pollinator populations.” (Goulson et al, 2011)

We also quote from the paper by Egler (1964)

“Finally the oft-lamented problems of the popularization of science lie precisely in these needs for “translation” when communicating to different Social Units. Jack Dement (1961) summarizes these problems in four basic maxims:

(A) Non-communicated science is non-existent science

(B) Non-communicable science is non-existent science

(C) Scientists do not speak the same language

(D) The science translator and re-jargonizer must be both science philologist and non-science philologist if he (or she) is to make "non-existent science" real."

12. Conclusions

Despite all the investment of time, money and expertise from governments, professionals and the interested public, biodiversity has nevertheless continued to decline in the UK over the last 50 years and the countryside has continued to become impoverished in quality. We put the question: why has much of this research not been acted upon or introduced into the public agenda?

The increasingly widespread use of neonicotinoid insecticides in agriculture presents a so far little-recognised risk to the natural world with its interlocking ecological systems on which human health and survival depends. In this manuscript we have collected together information from a number of published sources, from books, journals, newspapers and reports from government and other organisations, university libraries, e-journals, The Web of Knowledge and some internet sources. We have pointed to research which shows destructive effects on non-target invertebrates (bees, butterflies and other vital pollinating insects), on birds, particularly those invertebrate-dependent for their food supplies. Soil and water may be widely contaminated through the leaching and persistent residues of these substances.

While much of the focus of this manuscript is on insecticides, in particular neonicotinoids, however, there is no doubt that the use of herbicides also has enormously reduced the flora within and adjacent to cereal fields and, as previously stated, the ecologist Norman Moore, even in 1962, wrote “The total ecological change must be immense” (Moore, 1962, cited in Potts, 1986).

There is plenty of evidence to show that one of the important factors in the decline of species is pesticides, and, while research into other areas of habitat degradation is being undertaken, pesticides has not had that attention in detail in the last twenty years, and this must be remedied immediately.

Concerted and informed action is needed. Part of the problem seems to be that organisations and government bodies that should be conserving and protecting wildlife seem to be complacent about societal concerns about pesticides and about their known risks. The bias appears to be heavily in favour of short-term profit, to farmers, to commercial business interests (supermarkets and chemical companies… etc. etc.) – “Feeding the world population” seems to be about making a profit out of shortages and human misery rather than compassion or common sense altruism. Why should government organisations and wildlife charities support these attitudes, rather than challenge and use their influence to change the basis of decision…..? At the very least, when farmers sign up for even small contributions to biodiversity such as agri-environment schemes, these should be monitored, evaluated and developed where possible.

There is no reason why the government (Defra) should not pursue farmers in the same way they pursue other recipients of grants and benefits in order to ensure the taxpayers’ money for agri-environment schemes is *delivering environmental public goods in agriculture.*

This manuscript is a contribution to broadening understanding to give force to the discussion and perhaps promote an accounting of the chemical companies who are themselves so powerful and influential. It remains to be seen whether individuals, NGO’s and government have the commitment finally to work together and confront the loss of biodiversity.

If people were prepared to change their attitudes and their practices, huge improvements could be made to the decline in biodiversity. What is needed is not know-how or permission from the public, but ….” the simple belief that it is possible”, that “things can be otherwise” (Bourdieu, 1990) and the will and determination to act for the Earth. Belief and determination, some of the better qualities of the human species. like the value of birds, cannot be measured or quantified — not Ecosystems Services for humans' benefit, but the reverse – humans engaged in the service of the ecosystem.

Biodiversity is not a side issue to be relegated to the end of everyone else's agenda and considered only when all other criteria have been satisfied (that is never). As the basis of future survival on this planet its needs must take centre stage.

Appendix 1

RELEVANCE FOR PESTICIDE RISK MANAGEMENT (Crane et al *Pest Manag Sci* 62: 5–19 (2006)

Responses from particular stakeholders and the general public are of relevance to pesticide risk assessment management if we accept that societal values should play a role in regulatory decision making. If this idea is accepted then greater incorporation of stakeholder and public values in the risk management of pesticides should include recognition of four main points:

1. Long-term adverse pesticide effects on populations of plants and animals or on microbial function are considered unacceptable and should be assessed within the geographical and temporal context of individual species' life histories.

2. Individual vertebrate deaths should be avoided if at all possible even if these deaths are unlikely to affect population size or viability and particularly if the organisms at risk are those that the public care about. If some deaths appear to be unavoidable from the use of a pesticide then a clear and transparent economic case for the use of this pesticide should be made and published. This may consider both the availability of alternative, less harmful products and the public's willingness to pay for any additional costs associated with non-authorization of the product.

3. It seems impossible before a marketing approval is issued to predict the potential long-term effects of a particular pesticide on all species and populations that may in the future be exposed. Post-approval monitoring is therefore an essential safeguard and effective monitoring and surveillance schemes for terrestrial and aquatic habitats should be integrated into the pesticide approval process if the public's values are to be upheld.

4. A substantial proportion of the public is unlikely to be satisfied by any risk mitigation for pesticides even if evidence shows that it results in negligible risks to the environment. This is because a section of the public holds value-based views that are largely impervious to further argument.

Appendix 2

Household pesticides   Soil Association

The following products contain neonicotinoids
http://www.soilassociation.org/Takeaction/Savethehoneybee/Householdpesticides/tabid/690/Default.aspx

Product	Neonicotinoid	Shops	Websites
Westland Bug Attack	Thiamethoxam	Wickes, B&Q	www.selections.com
Westland Plant Rescue Bug Killer	Thiamethoxam	B&Q	
Baby Bio House Plant Insecticide	Thiacloprid	B&Q, Morrisons	www.bayergarden.co.uk
Provado Vine Weevil Killer	Thiacloprid	Wilkinsons	www.bayergarden.co.uk www.selections.com www.wyevale.co.uk www.plantandlife.com
Bug Clear Ultra Vine Weevil Killer	Acetamiprid	Wilkinsons	
Bug Clear Ultra For Flowering Plants	Acetamiprid	Wilkinsons	
Bug Clear Gun!	Acetamiprid	Wilkinsons	www.wyevale.co.uk
Provado Ultimate Bug Killer Spray	Imidacloprid		www.bayergarden.co.uk www.selections.com www.wyevale.co.uk www.plantandlife.com
Bayer Provado Systemic Ultimate Bug Killer	Thiacloprid		www.wyevale.co.uk
Provado Lawn Grub Killer	Imidacloprid		www.bayergarden.co.uk www.wyevale.co.uk www.plantandlife.com
Provado Lawn Grub Killer (for smaller lawns)	Imidacloprid		www.selections.com www.plantandlife.com
Provado Ultimate Bug Killer Ready to Use	Thiacloprid	Wilkinsons	www.bayergarden.co.uk www.selections.com www.wyevale.co.uk www.plantandlife.com
Provado Ultimate Bug Killer Concentrate	Thiacloprid	Wilkinsons	www.bayergarden.co.uk www.selections.com www.wyevale.co.uk

Appendix 3

Political issues

Parliamentary Debate House of Commons 25 JANUARY 2011 Neonicotinoid Pesticides Hansard.
http://www.publications.parliament.uk/pa/cm201011/cmhansrd/chan105.pdf

The Independent March 29th 2011
http://www.independent.co.uk/opinion/commentators/michael-mccarthy-a-scientist-with-the-credentials-to-take-on-defra-2255729.html

The Independent March 29th 2011
http://www.independent.co.uk/news/science/coalition-adviser-orders-review-of-safe-pesticides-2255728.html

The Independent March 30th 2011
http://www.independent.co.uk/environment/nature/government-asked-to-investigate-new-pesticide-link-to-bee-decline-2256737.html

The Independent April 5th 2011

http://www.independent.co.uk/environment/nature/study-reveals-how-bees-reject-toxic-pesticides-2262451.html

National Farmers Union websites
http://www.nfuonline.com/
http://www.nfuonline.com/Our-work/Animal-and-Plant-Health/Bee-health/Lies,-damn-lies-and-bee-stories-in-the-national-press/

Defra.
The Farming Regulation Task Force's report to Government on ways of reducing regulatory burdens on farmers and food processors, published on 17 May 2011, has recommended more than 200 ways of reducing unnecessary "red tape".

"Pesticides must be regulated in order to protect human health and the environment, but the continued availability of an adequate range of effective pesticides is critical to sustainable food production. We recommend that:
- **Defra should continue to lobby in the EU for a regulatory system governing pesticides that is based on risk not hazard; and**
- **in the short term, Defra facilitates adequate availability of pesticides (including for minor crops)."**

Farming Regulation Task Force report

Summary of recommendations

Appendix 4

Smiths Gore & RSPB: Managing Farmland For Wildlife

Media release – June 04, 2009

Wildlife-friendly farming ensures all can profit

Growing wildlife friendly crops is more profitable than growing wheat, a new study has concluded.

The RSPB and rural property advisers Smiths Gore have joined forces to investigate the profitability of managing farmland for wildlife in England and the results show growing seed crops for birds or nectar crops for insects makes sound financial sense for farmers.

Researchers at Smiths Gore have done the sums on a raft of environmental management measures used on the RSPB’s Hope Farm in Cambridgeshire to tackle farmland bird declines. The final balance sheet shows that environmental payments in the form of Entry Level Stewardship payments fully compensate for the income lost when a farm moves from crop production to environmental management. And smart use of these options can turn around a tidy profit.

“Our aim at Hope Farm has always been to show that including wildlife friendly environmental measures on farmland does not mean waving goodbye to profits,” said RSPB’s farm manager, Chris Bailey.

“There are many birds and other wild animals which depend on farmland, so it’s essential that agriculture remains a financially viable business. We want to work with farmers to help protect wildlife habitats on their land, but we definitely don’t want them to go bankrupt in the process.

“This study by the RSPB and Smiths Gore will provide reassurance for many farmers who have heard about our work here but are worried about how these measures will affect their bottom line.”

The two organisations will be presenting the figures in a series of leaflets for farmers at Cereals 09 in Cambridgeshire on June 10 and 11, the biggest agricultural show for arable farmers in the UK. There will be an opportunity for farmers to calculate figures for their environmental work using a calculator on the Smiths Gore website -www.smithsgore.co.uk/publications

The Farmland Bird Indicator on Hope Farm has increased by 119% since 2000 by simply boosting the availability of seeds and insects, the two key elements of the diet of declining species.

Chris Bailey added: “‘Many farmers have gone into ELS with hedges and buffer strips, which have high value for some wildlife, but we have found that diversifying the mix of options with ones that specifically deliver seeds and insects make all the difference.

“Skylark plots in our winter wheat have certainly helped double our skylark population since 2000, and now ELS payments give us a better gross margin too.”

Simon Blandford, Head of Farm Management at Smiths Gore said: “Our research has shown that ELS payments for environmental management measures really can outweigh any income lost by moving away from commercial crop production.

“With an ever increasing need for farm businesses to watch the bottom line, it is reassuring that by doing the right thing for wildlife, farmers can make a profit - it’s a true win-win for farmers and the environment.”

Hope Farm populations of the farmland bird species that have declined nationally, for the time when RSPB took management of the farm in 2000 and the most recent figures for 2008 http://www.smithsgore.co.uk/news-smiths-gore/smiths-gore-rspb-managing-13853

Species	National decline 1967-2005	Hope Farm population 2000	Hope Farm population 2008
Grey partridge	87%	0	3
Lapwing	33%	0	1
Skylark	59%	10	23
Yellow wagtail	70%	0	5
Starling	83%	3	17
Linnet	71%	6	18
Yellowhammer	55%	14	35
Reed bunting	21%	3	9

Appendix 5

Development of indicator species to measure pesticide impact on farmland wildlife – Defra PS2313

http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=ProjectList&Completed=0&KeywordID=15149

Description

It is notoriously difficult to monitor the impact of pesticide use on farmland wildlife, especially birds. What is needed, as identified by the Outcomes and Indicators Subgroup of the Pesticide Forum, is a robust and practical indicator of pesticide impact on farmland wildife, for use in measuring the success of the government's Pesticide Impact Reduction Policy. This proposal seeks to construct such an indicator, based on sampling invertebrate abundance and weed occurrence in cereals.
The impact of pesticide use on these taxa, many of which are eaten by farmland birds, is well known thanks not least to a comprehensive long-term study of the cereal ecosystem by The Game Conservancy Trust (GCT). This study combines 35 years of data on cereal weeds and invertebrates in Sussex with detailed long-term information on field-scale pesticide use; it is one of the largest of its kind in the world. An analysis of the first 26 years of data linked pesticide use to impacts on farmland wildlife at a wider scale than previously demonstrated. Regulatory authorities need to be confident that these findings remain valid and are typical of a wider spectrum of cereal-growing areas.
We propose to update the information on pesticide use, and determine whether the relationships between pesticide use and changes in weed occurrence and invertebrate abundance still hold, paying particular attention to the effect of recent changes in pesticides approved for use, as well as the effect of other aspects of the farmed environment, e.g. crop type, rotations and timing of pesticide application. Additionally, the GCT has collected similar information over the last 12 years from Leicestershire (Loddington), thereby providing an independent long-term dataset enabling further examination of the links between pesticide use and changes in wildlife abundance. By comparing pesticide usage on these areas with nationally available figures, we can gauge how representative of UK cereal growing are the Sussex and Loddington datasets.
Finally, we will determine which groups of invertebrates and plants are most consistently sensitive to pesticide use in the field. Of special interest will be chick food indices and weed indices encompassing important food items for farmland birds, as recommended by the Wider Biodiversity Project (PS2403). This knowledge will be used to develop one or more wildlife indicators of pesticide impact, and produce an evaluation of their strengths and weaknesses as proxy indicators of the national picture. Having two study sites to determine the effectiveness of the indicator will help to determine its usefulness over areas outside the south-east of England.

From the Executive Summary (1-25)

20. In Sussex, all nine invertebrate taxa and indices declined with insecticide use (five significant), number of insecticide applications (all significant) and use of insecticides in the autumn and spring (five and seven significant respectively). At Loddington this pattern held true for leaf beetles & weevils, plant bugs/hoppers and CFI (grey partridge chick food index), whilst aphids and YHI (yellowhammer index) increased with insecticide use, number of insecticide applications and spring insecticide use. The differences were probably due to differences in the types of insecticides used and the manner of application.

21. At Loddington, insecticide use was restricted almost exclusively to pyrethroids; the use of this insecticide group was associated with declines in the abundance of caterpillars and of plant bugs/hoppers at both sites. In Sussex, the use of systemic and non-systemic organophosphates was associated with declines in all nine taxa (significant in eight), whereas for pirimicarb only leaf beetles & weevils showed a decline, which was marginal and not significant.

References

Abram, D. (1996) *The Spell of the Sensuous: Perception and Language in a More-Than-Human World.* Vintage Books, Random House, New York.

Ade, C.M. et al (2010) Effects of an Insecticide and Potential Predators on Green Frogs and Northern Cricket Frogs. In: *Journal of Herpetology,* Vol. **44,** No. 4. pp. 591-600, 2010

Alaux, C. et al, (2010) Interactions between *Nosema* microspores and a neonicotinoid weaken honeybees (*Apis mellifera)* In: *Environmental Microbiology* 2010*,* **12** (3) 774-782*.*

Alexander, A.C. et al (2007) Effects of Insecticide Exposure on Feeding Inhibition in Mayflies and Oligochaetes, In: *Environmental Toxicology and Chemistry*, **26**, No. 8, pp. 1726–1732, 2007

Alford, D.V. (2011) *Plant Pests: A Natural History of Pests of Farms and Gardens.* Collins, London.

Angelier, F. et al (2009) Does stress response predict return rate in a migratory bird species? A study of American redstarts and their non-breeding habitat. In: *Proc. R. Soc. B* (2009) **276**, 3545–3551

Attwood, S.J. et al (2009) Declining birds in Australian agricultural landscapes may benefit from aspects of the European agri-environment model in: *Biological Conservation* **142**, 1981–1991

Baldi, A. and Batary, P. (2011) The past and future of farmland birds in Hungary. In: *Bird Study* (2011) **58**, 365–377

Barker, D. and Barker, R.M. (2011) Is “The Crop Protection Industry” Creating Another Silent Spring? In: *In Practice, Bulletin of the Institute of Ecology and Environmental Management.* No. **71**, 28-31 March 2011.

Bassett, P. (1980) *A List of the Historical Records of the RSPB*. (Birmingham. 1980) p.v.

Batary, P., et al (2011). Does habitat heterogeneity increase farmland biodiversity? *Front. Ecol. Environ*. **9**: 152–153.

Baylis, A.D. (2000) Why glyphosate is a global herbicide: strengths, weaknesses and prospects. In: Pest Manag Sci 56:299-308 (2000)

BBC Panorama, (2010) Panorama: Britain's Disappearing Wildlife BBC One, Monday 30 August at 2030 BST: web address**:** http://news.bbc.co.uk/panorama/hi/front_page/newsid_8950000/8950389.stm

Begon, M. et al (1996) *Ecology: Individuals, Populations and Communities*, Blackwell Science, Oxford

Beketov, M.A, and Liess, M. (2008a), Acute and Delayed Effects of the Neonicotinoid Insecticide Thiacloprid on Seven Freshwater Arthropods, In: *Environmental Toxicology and Chemistry*, **27**, No. 2, 461–470, 2008

Beketov, M.A, and Liess, M. (2008b), Potential of 11 Pesticides to Initiate Downstream Drift of Stream Macroinvertebrates. In: *Arch Environ Contam Toxicol (2008)* **55**:247–253

Benton, T.G. et al (2003) Farmland biodiversity: is habitat heterogeneity the key? In: *TRENDS in Ecology and Evolution* Vol.**18**, No.4, 182-188

Bianchi, F.J.J. A. et al (2010) Spatial variability in ecosystem services: simple rules for predator-mediated pest suppression In: *Ecological Applications*, **20** (8), 2010, pp. 2322–2333.

Biesmeijer, J.C. et al (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. In: *Science* **313,** 351-354

Bjork, L. (2010) Role of pesticides in UK farmland bird decline. In. *Pesticide News*, No. **90** December, 2010. 3-5.

Blake R. J. et al (2011) Enhancing habitat to help the plight of the bumblebee. In: *Pest Management Sci.* 2011; **67**: 377–379

Boatman, N. et al (2004) Evidence of the indirect effect of pesticides on farmland birds In: *Ibis* (2004) **146,** (Suppl. 2) 131-143

Bonmatin, J. M. et al (2004) Behaviour of Imidacloprid in Fields: Toxicity for Honeybees. In: *Environmental Chemistry: Green Chemistry and Pollutants in Ecosystems* Ch 44, Springer.
Bourdieu, P. (1990) *The Logic of Practice.* tr Nice, R. Cambridge, Polity Press.
Bouvier, J-C. et al (2011) Apple Orchard Pest Control Strategies Affect Bird Communities In South-eastern France. In: *Environmental Toxicology and Chemistry*, Vol. **30**, No. 1, pp. 212–219, 2011
Bowers, J. (1999) Policy instruments for the conservation of remnant vegetation on private land. In: *Biological Conservation*, **87**, 327-339.
Bradbury, R. B. et al (2010) Lowland farmland bird conservation in the context of wider ecosystem service delivery. In: *Journal of Applied Ecology* **47***,* 986-993
Brickle, N. et al (2000) Effects of agricultural intensification on the breeding success of corn buntings Miliaria calandra. In: *Journal of Applied Ecology* ***37****,* 742-755.
Bruce, A. Lyall, C. & Tait, J**.** (2001) People's Values in Relation to Chemicals and their Effects on Humans and the Natural Environment. Report to The Royal Commission on Environmental Pollution, 2001, SUPRA Paper no. 23.
Buckingham, D.L. and Peach, W.J. (2006) Leaving final-cut grass silage in situ overwinter as a seed resource for declining farmland birds. In: *Biodiversity and Conservation* (2006) **15**: 3827–3845
Carlile, W.R. (2006) *Pesticide Selectivity, Health and Environment,* CUP.
Carson, R. (1[st] publ.1962) *Silent Spring,* Penguin Classics (2000)
Casida, J.E. & Quistad, G.B. (1998) The Golden Age of Insecticide Research: Past, Present, or Future? In: *Annu. Rev. Entomol,* 1998*.* **43**:1-16
Chamberlain, D.E and Vickery, J. (2002). Declining farmland birds: evidence from large-scale monitoring studies in the UK. In: *British Birds* **95:** 300–310.
Chávez-Zichinelli, C.A. et al (2010) Stress responses of the House Sparrow (Passer domesticus) to different urban land uses. In: *Landscape and Urban Planning* **98** (2010) 183–189
Cloyda, R.A & Bethkeb,J. A, (2011) Impact of neonicotinoid insecticides on natural enemies in greenhouse and interiorscape environments. In: *Pest Manag Sci* 2011; **67**: 3–9
Collins, S. (1964) Pesticides and the Living landscape-Special book review. In: *Bioscience* Vol. **14** No. 11, Nov. 1964 37-38.
Conrad, K.F. et al (2006) Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. In: *Biological Conservation* Vol: **132**, 279-291
Cooper, J. and Dobson, H. (2007) The benefits of pesticides to mankind and the environment. In: *Crop Protection* **26**, 1337-1348.
Crane, M. et al (2006) Acceptability of pesticide impacts on the environment: what do United Kingdom stakeholders and the public value? *Pest Manag Sci* **62**: 5–19 (2006)
Cresswell, J.E. (2011) A Meta-analysis of experiments testing the effects of a neonicotinoid insecticide (imidacloprid) on honey bees. In: *Ecotoxicology* (2011) **20**: 149-157
Crick, H.Q.P, et al (1991). Seasonal patterns in apparent mortality rates of some seed-eating birds. In: Crick H.P.Q., Donald P.F. and Greenwood J.J.D. (Eds), Population processes in some British Seed-eating Birds*. BTO Research Report* No. **80**. British Trust for Ornithology, Thetford, UK, pp 126–146.
Daily, G.C, ed. (1997) *Nature's Services: Societal Dependence on Natural Ecosystems*, Island Press, Washington DC.
Davis, B.N.K., Lakhani, K.H. & Yates, T.J. (1991) The hazards of insecticides to butterflies of field margins. In: *Agriculture Ecosystems and Environment,* **36** (1991), 151-161
De Laet, J & Summers-Smith, J.D. (2007). The status of the house sparrow *Passer Domesticus* in north-western Europe: a review. In: *J. Ornithol*. (2007) **148**, (Supp 2): S275-278
Dement, J. (1961) Translating and re-jargonizing the little languages of science. In: *J. Chem. Educ*., **38**, (415), 415-417
Desneux, N. et al (2007) The Sublethal Effects of Pesticides on Beneficial Arthropods. In: *Annu. Rev. Entomology*. 2007. **52**: 81-106.

Dicks, L. & Sutherland, S.J. (2011) Evidence-Based Conservation on Farmland – Making it Possible. In: *In Practice* IEEM. **71** p16-18 March 2011
Dilworth, C. (2010) *Too Smart for our Own Good-The Ecological Predicament of Humankind*. Cambridge University Press. Cambridge
Dittbrenner, N, et al (2010) Physiological and behavioural effects of imidacloprid on two ecologically relevant earthworm species (*Lumbricus terrestris* and *Aporrectodea caliginosa*). In: *Ecotoxicology* (2010) **19**:1567–1573
Dittbrenner, N. et al (In Press) Sensitivity of Eisenia fetida in comparison to Aporrectodea caliginosa and Lumbricus terrestris after imidacloprid exposure. Body mass change and histopathology. In: *J Soils Sediments*
Doxa, A. et al, (2010) Low-intensity agriculture increases farmland bird abundances in France In: *Journal of Applied Ecology 2010,* **47**, 1348-1356.
Duzguner, V. & Erdogan, S. (2010) Acute oxidant and inflammatory effects of imidacloprid on the mammalian central nervous system and liver in rats. In: *Pesticide Biochemistry and Physiology* **97** (2010) 13-18
European Food Safety Authority (EFSA) (2009). Guidance document of the scientific panel for plant protection products and their residues for the risk assessments for birds and mammals under Council Directive 91/414/EEC. The EFSA Journal 2009.
Egler, F. E. (1964) Pesticides in our Ecosystem: Communication II. In: *Bioscience* Vol **14**, 11, November 1964
Egler, F. E. (1966) Pointed perspectives: pesticides in our ecosystem. In: *Ecology* **47**: 1077–1084, 1966
Elbert, A. et al (2008) Mini-review. Applied aspects of neonicotinoid uses in crop protection. In: *Pest Manag Sci* **64**: 1099–1105 (2008)
Evans, A. et al (2004) Importance of over-wintered stubble for farmland bird recovery: a reply to Potts. In: *Bird Study*, **51**, 94-96.
Fahrig, L. and Merriam, G. (1994) Conservation of fragmented populations. In: *Conservation Biology*, **8**, 50-59.
Ferreira, N.G.C. et al (2010) Habitats: Can they stress birds? An example of the use of biomarkers as an evaluation tool. In: *Integrated Environmental Assessment and Management* Vol **6**, No 4 pp. 779–780
Field, R.H. et al (2011) The provision of winter bird food by the English Environmental Stewardship scheme. In: *Ibis* (2011) **153**, 14-26.
Firbank, L.G. et al (Eds.) (1991) *The Ecology of Temperate Cereal Fields*, Blackwell, Oxford.
Foley J.A. et al (2005) Global Consequences of Land Use. In: *Science* **309,** 22 July 2005, 570-4
Forbush, E. H. (1907). *Useful birds and their protection*. Wright and Potter Printing Company, Boston.
Fox, R. et al (2001) *The State of Britain's Butterflies*. Butterfly Conservation, CEH and JNCC, Wareham, Dorset.
Fox, R. et al (2006) *The State of Britain's Larger Moths 2006*. Butterfly Conservation and Rothamstead Research, Wareham Dorset
Fox, R. et al. (2007) *The State of Britain's Butterflies 2007***.** Butterfly Conservation and the Centre for Ecology and Hydrology, Wareham, Dorset.
Frampton, G.K, and Dorne JL.C.M, (2007) The effects on terrestrial invertebrates of reducing pesticide inputs In Arable Crop Edges: A Meta-Analysis. In: *Journal of Applied Ecology* 2007 **44**, 362–373
Franklin, M.T. et al (2004) Effects of Clothianidin on *Bombus impatiens (Hymenoptera:* Apidae) Colony Health and Foraging Ability. In: *J. Econ. Entomol*. **97** (2): 369-373
Geiger, F. et al (2010) Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. In: *Basic and Applied Ecology* **11** (2010) 97–105
Gibson, R.H. et al (2007) Plant diversity and land use under organic and conventional agriculture: a whole-farm approach. *J. Appl. Eco*l. **44**, 792–803.

Girolami, V. et al, (2009) Translocation of Neonicotinoid Insecticides, From Coated Seeds to Seedling Guttation Drops: A Novel Way of Intoxication for Bees. In: *J.Econ. Entomol.* **102** (5):1808-1815
Goulson, D. et al (2011) Translating research into action; bumblebee conservation as a case study, In: *Journal of Applied Ecology* 2011, **48**, 3–8
Gressel, J. (2011a) Global advances in weed management. In: *Journal of Agricultural Science* (2011), **149**, 47–53.
Gressel, J. (2011b) Low pesticide rates may hasten the evolution of resistance by increasing mutation frequencies. In: *Pest Management Science* 2011 **67**: 253–257
Gupta, S. Gajbhiye, Æ V.T Gupta, Æ R. K.(2008) Soil Dissipation and Leaching Behaviour of a Neonicotinoid Insecticide Thiamethoxam. In: *Bull Environ Contam Toxicol* (2008) **80**: 431–437
Gustafson, D.I. (2011) Climate change: a crop protection challenge for the twenty-first century. In: *Pest Manag Sci* 2011; **67**: 691–696
Hart, J.D. et al (2006) The relationship between yellowhammer breeding performance, arthropod abundance and insecticide applications on arable farmland. In: *Journal of Applied Ecology,* 2006, **4***,* 81–91.
Harding, S. (2006) *Animate Earth: Science, Intuition and Gaia*. Green Books, Devon.
Haskell, D. (1994) Experimental evidence that nestling begging behaviour incurs a cost due to nest predation. *Proceedings of the Royal Society of London, Series B-Biological Sciences*, **257**, 161–164.
Hawes, C. et al (2010) Arable plant communities as indicators of farming practice. In: *Agriculture, Ecosystems and Environmen*t **138** (2010) 17–26
Heinz, G.H. (1989) How Lethal Are Sublethal Effects? In *Environmental Toxicology and Chemistry*, Vol **8**, pp 463-464, 1989
Huxley, J. (1962) Preface to Carson's *Silent Spring,* as above.
Jeschke, P. and Nauen, R. (2008) Neonicotinoids – From Zero to Hero in Insecticide Chemistry. In: *Pest Management Science* **64.** 1084-1098
Jeschke, P. et al (2011) Overview of the Status and Global Strategy for Neonicotinoids. In: *J. Agric. Food Chem*. 2011, **59**, 2897–2908
Jones, G.A. et al (2005) Avian Diversity and Functional Insectivory on North-Central Florida Farmlands. In: *Conservation Biology* Volume **19**, No. 4, August 2005, 1234–1245
Kleijn, D. and Sutherland, W. J. (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? In: *Journal of Applied Ecology*, **40**, 947-969
Kragten, S. et al (2010) Abundance of invertebrate prey for birds on organic and conventional arable farms in the Netherlands. In: *Bird Conservation International*, Vol **21**, issue 1, pp 1-11
Krebs, J.R. et al (1999) The Second Silent Spring in: *Nature* vol. **400**, 12 August, 1999, 611 -612.
Kreutzweiser, D.P, Thompson, D.G, Scarr, T.A (2009) Imidacloprid in leaves from systemically treated trees may inhibit litter breakdown by non-target invertebrates. In: *Ecotoxicol. Environ. Saf* **72.** 1053–1057
Kunz, T.H. et al (2011) Ecosystem services provided by bats. In: *Ann. N.Y. Acad. Sci*. **1223** (2011) 1–38
Leopold, A. (1968) A *Sand County Almanac*. Oxford University Press paperback 1968.
Macdonald, D.W. and Smith, H. (1990) Dispersal, dispersion and conservation in the agricultural ecosystem. *Species Dispersal in Agricultural Habitats*. (ed. Bunce, R.G.H. and Howard, D.C). p. 18-64. Belhaven Press
Mackay, D. and Barnthouse, L. (2010) Integrated Risk Assessment of Household Chemicals and Consumer Products: Addressing Concerns About Triclosan. In: *Integrated Environmental Assessment and Management*. Vol. **6**, No. 3, 390–392.
Macy, J. and Brown, M.Y, (1998), *Coming Back to Life; Practices to Reconnect Our Lives, Our World.* New Society Publishers, Canada.

Manning, A.D. et al (2006) Scattered trees are keystone structures – implications for conservation. In: *Biological Conservation* Vol. **132**, 311-321
Martin, B. (1996) Critics of Pesticides: whistleblower or suppression of dissent? In: *Philosophy and Social Action*, Vol. **22**, No. 3 pp. 33-55.
Maus, C. and Nauen, R. (2011) Response to the publication: Tennekes, H.A. (2010): The significance of the Druckrey–Küpfmüller equation for risk assessment—The toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time In: *Toxicology* **280** (2011) 176–177.
Mellanby, K. (1970) *Pesticides and Pollution* 2nd Edition. Collins, London.
Maini, S. Medrzycki, P. & Porrini, C. (2010) The puzzle of honeybee losses: a brief review. In: *Bulletin of Insectology* **63** (1) 153-160
Mineau, P. (2011) Barking Up The Wrong Perch: Why We Should Stop Ignoring Non-Dietary Routes Of Pesticide Exposure In Birds. In: *Integrated Environmental Assessment and Management.* Vol. **7**, No. 2, 297–299
Moffat, A.S (1993) New Chemicals Seek to Outwit Insect Pests. In: *Science* **261** (5121)550-1
Mols, C.M.M. and Visser, M.E. (2002) Great tits can reduce caterpillar damage in apple orchards. In: *Journal of Applied Ecology* 2002 **39**, 888–899
Mols, C.M.M. and Visser, M.E. (2007) Great Tits (Parus major) Reduce Caterpillar Damage in Commercial Apple Orchards. In: *PLoS ONE* **2** (2): e202. doi:10.1371/journal.pone.0000202
Mommaerts, V. et al (2010) Risk assessment for side-effects of neonicotinoids against bumblebees with and without impairing foraging behaviour. In: *Ecotoxicology* (2010) **19**, 207–215
Moore, N.W. (1962) Toxic Chemicals and Birds: The ecological background to conservation problems. In: *British Birds* **55** 428-435.
Moore, N.W. (1964) Foreword to Rudd's *Pesticides and the Living Landscape* as below
Moore, N.W. (1966) Pesticides in the Environment and Their Effects on Wildlife. In: *Journal of Applied Ecology*, Vol. **3** June 1966 Supplement.
Moore, N.W. (1967) The Effects of Pesticides on Wildlife, In: *Proceedings of the Royal Society of London.* Vol. **167**, No. 1007, Feb. 21.
Moore, N.W. (1987). *The Bird of Time*. Cambridge University Press. Cambridge.
Morandin, L.A. and Winston, M.L. (2003) Effects of Novel Pesticides on Bumble Bee (Hymenoptera Apidae) Colony Health and Foraging Ability. In: *Environ. Entomol*. **32** (3): 555-563
Moreby, S.J. Sotherton, N.W. &. Jepson PC (1997) The Effects of Pesticides on Species of Non-target Heteroptera Inhabiting Cereal Fields in Southern England. In: *Pestic. Sci.* 1997, **51**, 39È48
Morris, S.A. and Thompson, H.M. (2011) Dehusking Of Seed By Small Mammals: Default Values For Use In Risk Assessment. In: *Integrated Environmental Assessment and Management* Vol**. 7**, No. 1, 147-148
Murphy, M. T. (2003). Avian population trends within the evolving agricultural landscape of eastern and central United States. *The Auk,* **120:** 20–34.
NFU, (2011) National Farmers Union, Lies, damn lies and bee stories in the national press.http://www.nfuonline.com/Our-work/Animal-and-Plant-Health/Bee-health/Lies,-damn- lies-and-bee-stories-in-the-national-press/
Najafi, G et al (2010) The Effect of Chronic Exposure with Imidacloprid Insecticide on Fertility in Mature Male Rats. In: *International Journal of Fertility & Sterility* Vol. **4** Issue 1. 9-16
Nauen, R. Denholm, I. Dennehy, T. and Nichols, R.(2008) News from the front line: reports from the Global Workshop on the Stewardship of Neonicotinoid Insecticides, Honolulu, Hawaii, 5–6 June 2008 In: *Pest Management Science* **64**:1082–1083
Neves, P. M.O.J & Alves, S. B. (2000) Grooming Capacity Inhibition in *Cornitermes cumulans* (Kollar) (Isoptera: Termitidae) Inoculated with Entomopathogenic Fungi and Treated With Imidacloprid. In: *An. Soc. Entomol. Brasil* **29** (3) 537-546. Set.2000
New, T.R. (2005) *Invertebrate Conservation and Agricultural Ecosystems,* CUP.

Newton, I. (1972) *Finches*, Collins, London
Newton, I. (1986) *The Sparrowhawk*, Calton: T. & A. D. Poyser. London.
Nørgaard, K.B & Cedergreen, N. (2010) Pesticide cocktails can interact synergistically on aquatic crustaceans. In: *Environ Sci Pollut. Res* (2010) **17**:957–967
Noss, R.F. (1996) The Naturalist Are Dying Off. In: *Conservation Biology*, Vol. **10** No.1 February, 1996.
O'Connor, R.J. & Shrubb, M. (1986) *Farming and Birds*, Cambridge University Press, Cambridge.
Oerke, E-C, et al (2010) *Precision Crop Protection - the Challenge and Use of Heterogeneity*. Springer Dordrecht Heidelberg London New York
Ormerod, S.J. & Watkinson A.R. (2000) Editors' Introduction, "Special Profile: Birds and Agriculture": In: *Journal of Applied Ecology* 2000 **37**, 699-705.
Pearl, J. (2005) Direct and Indirect Effects, In: *Proceedings of the American Statistical Association Joint Statistical Meetings*, 1572-1581, August 2005.
Pearl, J. (In Press) The Causal Mediation Formula – A practitioner guide to the assessment of causal pathways, Technical Report R-379 February 2011 *Proceedings of the American Statistical Association Joint Statistical Meetings*)
Perfecto, I. et al, (2009) *Nature's Matrix; Linking Agriculture, Conservation and Food Sovereignty*, Earthscan, London.
Peterjohn, B. G. (2003). Agricultural landscapes: can they support healthy bird populations as well as farm products? *Auk* **120:** 14–19.
Pickett S. R. A. and Siriwardena, G. M. (In Press) The relationship between multi-scale habitat heterogeneity and farmland bird abundance. In: *Ecography*
Pilling, E.D. & Jepson, P.C. (1993) Synergism between EBI fungicides and a pyrethroid insecticide in the honeybee (Apis mellifera L). In: *Pesticide Science***, 39,** 293-299.
Pilling, E.D. et al (1995) Mechanism of Synergism between the Pyrethroid Insecticide λ-Cyhalothrin and the Imidazole Fungicide Prochloraz, in the Honeybee (Apis mellifera L). In: *Pesticide Biochemistry and Physiology* **51**, 1-11 (1995).
Pimentel, D & Lehmann, H. (1993) "*The Pesticide Question".* Chapman and Hall, New York
Pimm, S.L. (1997) The value of everything. In: *Nature* Vol: **387**, May 15 1997, 231-232.

Potts, G.R. (1986) *The Partridge; Pesticides, Predation and Conservation.* Collins, London.
Potts, G.R. (1991) The Environmental and Ecological Importance of Cereal Fields. In: Firbank, L.G. et al (Eds.) (1991) *The Ecology of Temperate Cereal Fields*, Blackwell, Oxford.
Potts, G.R. (2003) The myth of overwintered stubble. In: *Bird Study*, **50**, 91-93.
Potts, G.R, Ewald, J. A. and Aebischer, N. J.(2010) Long-term changes in the flora of the cereal ecosystem on the Sussex Downs, England, focusing on the years 1968–2005 In: *Journal of Applied Ecology 2010,* **47**, 215-226 Game & Wildlife Conservation Trust
Potts, S.G. et al ((2010) Global pollinator declines: trends, impacts and drivers. In: *Trends in Ecology and Evolution* Vol.**25** No.6 345-353
Potts, S.G. et al (2011) Developing European conservation and mitigation tools for pollination services: approaches of the STEP (Status and Trends of European Pollinators) project. In: *Journal of Apicultural Research*, Vol. **50** issue 2, 152-164
Pretty, J. et al (2008) Multi-year assessment of Unilever's progress towards agricultural sustainability I: indicators, methodology and pilot farm results. In: *International Journal of Agricultural Sustainability* **6** (1) 2008, 37–62
Prosser, P and Hart, A.D.M. (2005) Assessing Potential Exposure Of Birds To Pesticide-Treated Seeds. In: *Ecotoxicology,* **14**, 679–691, 2005.
Ratcliffe, D. A. (1970) Changes Attributable To Pesticides In Egg Breakage Frequency And Eggshell Thickness In Some British Birds. In: *Journal of Applied Ecology*, Vol. **7**, No. 1 (1970), pp. 67-115
Ratcliffe, D. A (1963) The status of the Peregrine in Great Britain 1963-4 In: *Bird Study* vol.**10,** 56-90.

Ratnieks, F.L.W. & Carreck, N.L. (2010) Clarity on honeybee collapse? In: S*cience* **327** (5962) 152-153

Redford, K.H. and Adams, W.M. (2009). Payment for Ecosystem Services and the Challenge of Saving Nature. In: *Conservation Biology*, Vol. **23**, No. 4, 785-787.

Redpath, S. (2011) Book Review. *In Search of Harriers: Over the Hills and Far Away* by D. Watson. (Langford Press Wildlife Art Series.) In: *Ibis* (2011), 153, 653–654

Rhymer, C.M, Robinson R.A, Smart, J &. Whittingham M.J, (2010) "Can ecosystem services be integrated with conservation? A case study of breeding waders on grassland. In: *Ibis* (2010), **152**, 698–712

RSPB (2008) *RSPB Research Report no 28, April 2008. A review of indirect effect of pesticides on birds*. RSPB, Sandy.

Rudd, R.L. (1964) *Pesticides and the Living Landscape*, Faber and Faber, London.

Sabbagh G. J et al (2002) Significance of binding on imidacloprid degradation in soils, and effects of soil characteristics on imidacloprid adsorption capacity, Vol 200327. *Bayer CropScience*, Stilwell, Kansas

Saunders, D.A., 1989. Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia. A case study. In: *Biological Conservation*, **50**, 99–135.

Schmuck, R. et al, (2003) Field Relevance of a synergistic effect observed in the laboratory between an EBI fungicide and a chloronicotinyl insecticide in the honeybee (*Apis mellifera* L, Hymenoptera) In: *Pest Management Science* **59:** 279-286

Scott-Dupree, C.D. et al (2009) Impact of Currently Used or Potentially Useful Insecticides for Canola Agroecosystems on *Bombus impatiens* (Hymenoptera: Apidae), *Megachile rotundata* (Hymentoptera: Megachilidae), and*Osmia lignaria* (Hymenoptera: Megachilidae). In: *J. Econ. Entomol*. **102** (1): 177Ð182 (2009)

Sekercioglu C.H. (2006) Increasing awareness of avian ecological function. In: *Trends Ecol. Evol.* **21:** 464–471.

Sheail, J. (1985) *Pesticides and Nature Conservation-The British Experience 1950-1975*. Clarendon Press, Oxford.

Shirangi, A. et al (2010) Living near agricultural pesticide applications and the risk of adverse reproductive outcomes: a review of the literature. In: *Paediatric and Perinatal Epidemiology,* **25**, 172–191. 2010.

Shrubb, M. (2003) *Birds, Scythes and Combines*. Cambridge University Press. Cambridge.

Sibly, R.M, Newton, I, & Walker, C.H. (2000). Effects of dieldrin on population growth rates of sparrowhawks 1963-1986 In: *Journal of Applied Ecology*, **37**, 540-546.

Siriwardena, G.M. et al (2008) Farmland birds and late winter food: does seed supply fail to meet demand? In: *Ibis*, **150**, 585-595

Smout, T.C. (2000) *Nature Contested: Environmental History in Scotland and Northern England since 1600*. Edinburgh University Press.

Sotherton, N.W. et al. (1985) Comparison of herbicide-treated and -untreated headlands and the survival of game and wildlife. In: *British Crop Protection Conf. Weeds,* vol **3** 991-998

Spivak, M, Mader, E. Vaughan, M. and Euliss, N.H. (2011) The Plight of the Bees. In: *Environmental Science and Technology.* 2011, **45**, 34-38.

Stoate, C. et al (2001) Ecological impacts of arable intensification in Europe. In: *Journal of Environmental Management* (2001) **63**, 337–365

Stoate, C. et al (2009) Ecological impacts of early 21st century agricultural change in Europe – A review. In: *Journal of Environmental Management* **91**, (2009) 22–46

Stoate, C. (2011) Can wildlife deliver the goods? Ecosystem services and wildlife conservation. In; *British Wildlife*, Vol. **22**, No. 3, 169-174

Storkey, J. and Westbury, D.B. (2007) Mini-Review Managing arable weeds for biodiversity In: *Pest Management Science* **63**:517–523 (2007)

Strauss, S.Y (1991). Indirect Effects in Community Ecology Their Definition Study and Importance. In: *TREE* vol. **6,** *no. 7, July 1991*

Summers-Smith, J.D. (1999) Current Status of the House Sparrow in Britain. In: *British Wildlife*, Vol. **10,** No. 6, 381-386
Summers-Smith, J.D. (2003) The decline of the house sparrow: a review. In: Brit. Birds, **96**, 439-446.
Swanton, C.J. et al (2011) Similarities between the discovery and regulation of pharmaceuticals and pesticides: in support of a better understanding of the risks and benefits of each. In: *Pest Manag Sci 2011*; **67**: 790–797
Tait, J. (2001) Pesticide regulation, product innovation and public attitudes. In: *J. Environ. Moni*t. Vol **3**, 64N-69N.
Tennekes, H, (2010a) The significance of the Druckrey–Küpfmüller equation for risk assessment—The toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time. In: *Toxicology* 2010 **276** 1–4
Tennekes, H, (2010b) *The systemic insecticides: a disaster in the making,* Weevers Walburg Communicatie, Zutphen, The Netherlands.
Thompson, H.M. and Maus, C. (2007) Perspective: The relevance of sub-lethal effects in honey bee testing for pesticide risk assessment. In: *Pest Manag Sci* **63**:1058–1061
Tilman, D. et al (1994) Habitat destruction and the extinction debt. In: *Nature* **371**, 65–66.
Tišler, T. et al (2009) Hazard identification of imidacloprid to aquatic environment. In: *Chemosphere* **76** (2009) 907–914
Tomizawa, M. & Casida, J. (2005) Neonicotinoid Insecticide Toxicology: Mechanisms of Selective Action. In: *Annu. Rev. Pharmacol. Toxicol*. 2005. **45**:247–68
Van den Bosch, R (1989) (first publ. 1978) *The Pesticide Conspiracy,* University of California Press, Berkeley.
Van den Brink P.J, (2008) Ecological risk assessment: From book-keeping to chemical stress ecology. In: *Environ Sci Technol* **42**:8999–9004.
Van der Weijden W., et al eds (2010) *Farmland birds across the world*. Lynx Edicions, Barcelona.
Vandermeer, J.H (2011) *The Ecology of Agroecosystems*, Jones and Bartlett Publishers, Sudbury, Mass.
Vidau, C. et al (2011) Exposure to Sublethal Doses of Fipronil and Thiacloprid Highly Increases Mortality of Honeybees Previously Infected by *Nosema ceranae* In*: PLoS ONE* ***6*** (6): e21550. doi:10.1371/journal.pone.0021550
Walker, C.H. (2003) Neurotoxic pesticides and behavioural effects upon birds, In: *Ecotoxicology*, **12,** 307-316, 2003.
Walker, C.H. et al (2005) *Principles of Ecotoxicology* 3rd edition. CRC Press.
Walker, C.H. (2008) *Organic Pollutants: An Ecotoxicological Perspective*. 2nd edition CRC Press
Walker, K.J. et al (2007) The conservation of arable plants on cereal field margins: An assessment of new agri-environment scheme options in England, UK.In: *Biological Conservation*, **136**, 260-270
Weed, C. M., and Dearborn, N. (1935). *Birds and their relations to man*. J. B. Lippincott, Philadelphia.
Wenning, R.J. (2011) "Broadening the Ecology in Ecological Risk Assessment" Editorial in: *Integrated Environmental Assessment and Management* Vol **7** No 2, 155
Whelan, C.J. et al (2008) Ecosystem Services Provided by Birds In: *Ann. N.Y. Acad. Sc*i. **1134**: 25–60 (2008)
Whittingham, M.J. (2011) The future of agri-environment schemes: biodiversity gains and ecosystem service delivery? *Journal of Applied Ecology* , **48**, 509–513
Wickramasinghe, L.P. et al, (2003) Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. In: *Journal of Applied Ecology* 2003, **40**, 984–993
Wickramasinghe, L.P. et al, (2004) Abundance and Species Richness of Nocturnal Insects on Organic and Conventional Farms: Effects of Agricultural Intensification on Bat Foraging. In: *Conservation Biology* Vol. **18**, No. 5, Oct. 2004

Wilson, J.D. et al (1999) A Review of the abundance and diversity of invertebrate and plant foods of granivorous birds in Northern Europe in relation to agricultural change, In: *Agriculture, Ecosystems and Environment* **75**: 13-30
Wilson, J.D, Evans, A.D., Grice, PV, (2009) *Bird Conservation and Agriculture,* CUP.
Wilson, J, et al (2010) Bird Conservation and Agriculture: a pivotal moment? In: *IBIS 2010* **152,** 176-179.
Winqvist, C. et al (2011) Mixed effects of organic farming and landscape complexity on farmland biodiversity and biological control potential across Europe. In: *Journal of Applied Ecology* 2011, **48**, 570–579
Winston, M.L. (1987) *The Biology of the Honey Bee.* Harvard University Press.
Winston, M.L. (1999) *Nature Wars: People vs. Pests,* Harvard University Press.

[1] The unique success of neonicotinoids is reflected in their turnover figures in 1990 as compared with 2005. In 1990, before launch of the first neonicotinoid insecticide imidacloprid, the agrochemical market, with a total volume of € 7.942 billion, was dominated by organophosphates (OPs) (43%), pyrethroids (18%) and carbamates (16%). In 2005, neonicotinoids had gained a market share of 16% from a total market of € 7.162 billion, mainly at the expense of OPs (25%) and carbamates (10%). The turnover figures for seed treatment are very impressive: a niche market of € 155 million for insecticidal seed treatment in 1990 was dominated by carbamates. It has been developed to a € 535 million market, with a share for neonicotinoid insecticides of 77% in 2005. (Elbert et al, Bayer Crop Science, 2008)

[2] In 1990, before the launch of the first neonicotinoid insecticide, imidacloprid, the agrochemical market (total volume of €7.942 billion) was dominated by organophosphates (OPs) (43%), pyrethroids (18%), and carbamates (16%). In 2008, neonicotinoids had gained a 24% share of a slightly decreased total market of €6.330 billion, mainly at the expense of OPs (13.6%) and carbamates (10.8%). On the other hand, the turnover figures for seed treatment are very impressive. A so-called niche market of €155 million for insecticidal seed treatment in 1990 was dominated by carbamates (77.4%). It has been developed to a €957 million market, with a share for neonicotinoid insecticides of 80% in 2008

[3] Huxley, J, In Preface to Carson's *Silent Spring*, 1962

[4] DDT caused eagle eggshells to become thin and the eggs to become sterile

[5] "The differences between the insecticides are: O*rganochlorines* (DDT) were stable in water and soil, but caused environmental problems. *Organophosphates* and *carbamates* are readily degradable in water and soil, but are highly toxic to mammals, *Neonicotinoids* are not readily degradable in water and soil, but of low toxicity to mammals. "The difference, though, is that imidacloprid and clothianidin are at least 7,000 times more toxic to honey bees, or any other insect for that matter, than DDT, (and I am only talking about acute toxicity here, the differences are even greater when it comes to chronic toxicity to insects). Now, admittedly, you need less of the neonics, because they are systemic but they easily leach from soils and spread through the environment killing non-target insects" (Henk Tennekes, pers.com). We (the authors) recognise that this Note is broad and rather simplistic. In fact, there is considerable variation in their chemical properties. For more detailed explanations of complex mixtures of chemicals consult Organic Pollutants: An Ecotoxicological Perspective 2nd edition (2008) by C.H. Walker, CRC Press.

[6] Neonicotinoids, OCs, OPs, carbamates and pyrethroids all act on the nervous system -- but there are different mechanisms of toxicity ie they have different sites of action -- acetylcholinesterase, sodium channels, GABA receptors and `nicotinic` receptors for acetylcholine. See Chapter 16 in Organic Pollutants 2nd Ed. (Colin H. Walker pers.comm)

[7] "Target site in insects is an insect's neuronal synapse where electrical impulses are transmitted from one cell (pre-synapse) to another (post-synapse)"*Syngenta Entomology 101*

[8] Classes of Neonicotinoids and Trade Names: Acetamiprid (Assail®, Intruder®), Clothianidin (Poncho®, Clutch®) Imidacloprid (Gaucho®, Admire®, Provado®) Thiamethoxam (Actara®, Centric®, Cruiser®, Platinum™) *Syngenta Entomology 101*

[9] Soil Association http://www.soilassociation.org

[10] Buglife Report http://www.buglife.org.uk/Resources/Buglife/Neonicotinoid%20insecticides%20report.pdf

[11] To clarify how insects are classified and named, "it needs to be borne in mind that insects belong to the great group of invertebrate animals known as the Arthropoda (Gr.*arthron,* a joint and *pous* , gen. *podos*, a foot)" A. D.Mimms *Insect Natural History,* Collins 1947.

[12] http://www.butterfly-conservation.org

[13] Brickle et al (2000) Agricultural intensification in Britain, including the increased use of pesticides, has led to a widespread decrease in the availability of chick-food invertebrates on lowland farmland. If our results are typical of corn buntings in an arable environment, this decrease correlates with reduced breeding success. Depending on the mortality rates for fledged chicks and older birds, this reduction may have contributed to the corn buntings' decline and may hamper recovery.

Hart et al (2006) demonstrated how insecticide applications can depress yellowhammer breeding productivity. We provide the requisite data for a framework that enables predictions to be made about the probable population effects of particular pesticide products. If the risk of indirect effects can be predicted accurately then appropriate mitigation and compensation measures could be incorporated into pesticide regulatory procedures and/or agri-environment schemes

[14] The Transgenic Treadmill: Before 1996, weeds were not observed to have evolved resistance to glyphosate in the field, but since then, the introduction of transgenic glyphosate tolerant crops has led to evolution of a number of resistant weeds as the result of the greatly increased use of the herbicide particularly during the post-emergent growth of the crops.

http://www.i-sis.org.uk/glyphosateResistanceTransgenicTreadmil.php

[15] "I think that the best terminology is that (rather than indirect/direct effects) it is a non-target effect, since the insecticides are not meant for the birds. One definition of an indirect effect is the effect of one species on another through the actions of a third. One could also interpret an indirect effect as the effect of one species on another through the effects of a third entity - in this case, the pesticide. Since the insecticide was sprayed on plants to hurt insects, and is not sprayed directly on the bird, they might call this an indirect effect. If the bird didn't eat the insect, the pesticide would have small to no effects on the birds. I agree with you, however, that the actions of the pesticide on birds are direct (poisoning it). Thus, sticking with 'non-target' as the terminology is probably the least ambiguous and best describes the effects of the pesticides on the birds." Sharon Y. Strauss, Professor, Evolution and Ecology. (pers.comm.)

[16] The total budget available for AES under the Rural Development Programme for England for the seven-year programme period (2007–2013) is £3.1 billion. This equates to an average of £446 million a year over the life of the programme.

http://www.naturalengland.org.uk/ourwork/farming/funding/aesiereport.aspx

[17] http://bou-online.blogspot.com/

[18] UNCED (1992) *Agenda 21, United Nations programme from Rio:* New York. United Nations, quoted in New (2005).

[19] Leaked EPA Memo http://www.panna.org/sites/default/files/Memo_Nov2010_Clothianidin_0.pdf

[20] According to the leaked EPA memo, clothianidin's registration is based on a flawed field study that was subsequently downgraded to a "supplemental" category that amounts to "interesting, but not enough to base a decision on." Clothianidin (product name "Poncho"®) has been widely used as a seed treatment on many of the US's major crops for eight growing seasons under a "conditional registration" granted in 2003 while EPA waited for Bayer to conduct the field study assessing the insecticide's toxicity to bees — the study that now appears to be too flawed to rely on.

[21] *http://www.beyondpesticides.org*

[22] http://www.defra.gov.uk/corporate/consult/pesticides/index.htm

[23] Responses. http://ww2.defra.gov.uk/news/2010/12/15/pesticides/

[24] The SUD is a progressive piece of EU legislation designed to reduce the risk of harm to humans and the environment from the use of pesticides. The Articles contained within the SUD covered a wide range of issues including training, information provision to the public, minimising and prohibiting the use of pesticides in specific areas and integrated pest management (IPM). The SUD is not a binding EU law but is open to interpretation on how it is implemented by individual Member States, although they must adhere to the spirit and meaning of the Directive and meet the required aims of the Directive.

[25] *http://www.pan-international.org*