Report Number
634

Integrated farming and biodiversity

English Nature Research Reports

working today
for nature tomorrow

Preface

English Nature recognises the interdependence of agriculture and nature conservation and we aim to work closely with farmers operating a variety of different agricultural systems to sustain biodiversity. The reform of the Common Agricultural Policy, which will be implemented from 2005, is commonly expected to initiate some of the biggest changes in agricultural land use for half a century. While some of the changes, such as wide availability of agri-environment schemes, might be expected to have a positive impact on farmland biodiversity the effect of others, such as an increased focus on markets, are more difficult to predict.

In determining its advice to others about how future policy should be developed English Nature needs to have a good, science based, understanding of the impacts of different farming practices so that policies can be developed to effectively encourage practices that bring biodiversity benefits.

In the light of these requirements this report brings together previous research to examine the impact of a suite of practices often bundled under the descriptors Integrated Crop Management or Integrated Farm Management. The findings of the study are not comprehensive as the existing research leaves large gaps in our understanding of the impact of Integrated Farm Management, particularly on grassland and horticultural farms. While comparison with equivalent conventional practice remains difficult as a consistent definition of 'Integrated' has not been adopted at the farm level and by researchers, there are some useful indications to come from this work:

Integrated practices generally reduce the amount of inputs (fertilisers and pesticides) used by farmers. While these studies did not measure if this reduction had any effect on the amount of these chemicals leaving the farm in ground and surface water flows (this issue could usefully be addressed by further research) it seems likely that the more considered application of reduced amounts of nutrients and chemicals will assist with natural resource protection both on and off the farm.

Integrated practices, in comparison with equivalent conventional practices, potentially do less damage to biodiversity and in many cases there is evidence that the abundance of common wildlife species already on the farm increases following the adoption of integrated management. These species can be important both in their own right and as resources for other species in the food web. However, this review has found scant evidence that Integrated practices increase either the diversity of wildlife species on the farms studied or assist the recovery of those species of farmland wildlife that are rare and / or declining.

This work is an initial indication that Integrated management may provide useful environmental benefits. English Nature will continue to monitor the development of these systems and the economic and other factors that influence their uptake to see if their performance can be further enhanced by, for example, the future development of agri-environment schemes.

Integrated systems have the advantage that many of their techniques are familiar to most farmers and the technological transfer and management changes needed to introduce them are generally small. On the basis of our present understanding Integrated systems could be adopted by the majority of farmers and should, perhaps, come to be regarded as the new baseline standard for UK agriculture. This report, however, provides no evidence to suggest that Integrated can be regarded as a best practice system for farmland biodiversity conservation.

Agriculture Unit
English Nature
March 2005-03-21

English Nature Research Reports

Number 634

Integrated farming and biodiversity

P. Berry, S. Ogilvy & S. Gardner
ADAS

March 2004

ISSN 0967-876X

Summary

The overall aim of this report is to provide English Nature with scientifically robust information to determine whether integrated farming systems have the capacity to deliver biodiversity benefits. Eleven European studies were identified which compared the biodiversity under an Integrated Farm Management (IFM) system with a conventionally managed system. Nine studies were all arable and two were mixed. On average, IFM reduced nitrogen use by 18%, herbicide use by 43%, fungicides by 50% and insecticides/ molluscicides by 55% compared with conventional management. In addition to the eleven key studies, 60 peer reviewed papers and technical reports describing IFM and biodiversity were reviewed.

The IFM studies showed that IFM in arable and mixed farms could cause a statistically significant increase in the biodiversity of plants, soil microflora, non-target arthropods, earthworms, birds and small mammals. None of the studies showed that IFM reduced biodiversity. Plant, arthropod and earthworm biodiversity were increased with most consistency. Microflora, birds and mammals were only recorded in one or two studies. The majority of the improvements in biodiversity were achieved by increasing the populations of existing species, apart from the number of plant species in one study and earthworm species in another study. IFM increased weed numbers above the economic threshold in some studies, but other pests were not problematic.

It was impossible to attribute many of the biodiversity changes to specific management practices due to the confounding effects of other factors. This problem is inherent within system comparison studies. The few instances when specific management practices were tested directly with experiments and literature driven hypotheses indicate that minimum cultivations, reduced herbicides and reduced insecticides (particularly methiocarb slug pellets) have positive effects on biodiversity. Crop type also had important effects on biodiversity. For example, spring sown crops were associated with more weeds, but were often negatively associated with arthropods, potatoes reduced earthworms, and using a cover crop on set-aside or using break crops favoured birds.

Extrapolating these observations to a landscape scale is not straight forward due to flexibility concerning which management practices can be used within an 'IFM system'. The IFM practices that future IFM farms employ will be influenced by economics, soil type and climate. The Mid-Term Review may result in fewer spring crops – which would reduce biodiversity, but greater set-aside - which would improve biodiversity. Minimal cultivations could be employed on significant areas, although its use is restricted by soil type, climate and the need to control grass weeds. Reduced herbicide and pesticide practices are likely to be used to cut costs. New agri-environmental schemes will increase the likelihood that future IFM farms employ wild life friendly management. On balance, it seems likely that if IFM becomes widely employed in the future, then biodiversity benefits would be seen at the landscape scale.

Gaps in knowledge include a lack of information about how IFM on grassland and horticultural farms affects biodiversity. The effect of specific management practices on biodiversity are not at all well understood. Specifically designed experiments are required to fill this gaps. Effects of IFM on small mammals and birds has also received little attention.

Contents

1. Introduction

The overall aim of this report is to provide English Nature with scientifically robust information to determine whether integrated farming systems have the capacity to deliver biodiversity benefits.

The specific objectives of this report are to:

- Identify the scientific basis for biodiversity impacts of IFM on farmland.
- Catalogue the relevant reports and journal articles relating to IFM and biodiversity.
- Identify the specific IFM measures, standards or practices that deliver most benefit or disbenefit to wildlife.
- Identify the gaps in knowledge with reference to IFM biodiversity.

There is no set definition of Integrated Farm Management (IFM). The European Initiative for Sustainable Development in Agriculture (EISA) (Anon 2003) describes IFM as 'A common sense whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, affordable food. It is not prescriptive because it is a dynamic concept: it must have the flexibility to be relevant on any farm, in any country, and it must always be receptive to change and technological advances.'

EISA has developed a codex which defines a set of common principles and practices for IFM.

Specific IFM principles include:

- Producing sufficient high quality food, fibre and industrial raw materials.
- Meeting the demands of society.
- Maintaining a viable farm business.
- Caring for the environment.
- Sustaining natural resources.

The codex describes ten practices to help farmers carry out IFM. The key practices that are likely to influence biodiversity include:

Monitoring and auditing

- Measurement of environmental indicators.
- Monitoring pest populations and control levels.

Crop protection

- Using resistant varieties, adjusting rotation, timing of cultivations and drilling.
- Being aware of economic thresholds for damage.
- Using pest control options that maximise human safety, minimise environmental impact and are economically justifiable.

Soil and water management

- Using cultivation practices that minimise damage to soil structure, such as minimum tillage.
- Taking measures to reduce erosion, eg green crop covers.

Crop nutrition

- Matching fertiliser applications with crop requirements.

Waste management and pollution prevention

- Storing fertilisers and crop protection products securely.
- Emergency action procedures to minimise risk of pollution from accidents.

Wildlife and landscape management

- Reducing the wildlife impact of operations such as ploughing, hedge cutting.
- Managing field margins to reduce pernicious weeds and encourage diverse flora and fauna.
- Creating, as far as possible, a diverse cropping pattern on the farm.
- Managing water courses and wet areas on the farm to encourage wild life.

Crop rotation and variety choice

- Choosing varieties and sowing dates that minimise pest problems.
- Managing cultivation and fertiliser treatments to improve soil structure/health.
- Using a cropping sequence and cultivations to reduce nitrate leaching and pest development.

Clearly, there are many management practices associated with IFM. For the purposes of this report, the minimum IFM practices that must be employed for a farming system to be defined as using IFM are a reduction in agro-chemical inputs compared with conventional management. Biodiversity is defined as an increase in both the number of individuals within a species or/and an increase in the number of species present within the experimental areas tested. The influence of agri-environmental schemes are considered when they form part of a particular IFM system. Where possible the effects of the agri-environmental schemes will be separated from other management factors. Kleijn and Sutherland (2003) provide a comprehensive review of the effects of European agri-environmental schemes on biodiversity.

The report only considers studies that compare IFM with conventional management and which have statistically analysed data. Therefore, the Allerton (Stoate and Leake 2002), Balancing Environment and Agriculture in the Marches (BEAM) (Wade 2001), Manor Farm, BUZZ, 3D Farming LINK and Northmoor Trust (Anon 2001) projects have not been included because these IFM farm studies were not compared with a conventionally managed farm. Effects on biodiversity are only reported if they are statistically significant at the 95% level.

2. Sources of information

2.1 The major IFM studies

Biodiversity has been monitored in eleven IFM studies in Europe since 1978, and the details of each study are described in Table 1. The key biodiversity findings are listed for each study in Appendix 1. In addition to the completed studies described, we have included the 'SAFFIE' project which has recently begun. Information from this study will be considered where appropriate.

The scale of the studies varies from 24m x 4m plots to blocks of fields. This has an important bearing upon what types of biodiversity can be measured. Meaningful statistical analysis is often difficult because scale must be balanced with replication. Nonetheless, statistical analyses have been carried out on all of the studies analysed. It is clear that most of the studies are on all arable rotations, with only two studies considering mixed farms and none considering horticultural enterprises. This represents a significant gap which will be discussed later.

The breadth of IFM techniques used by each study was variable. For example, the SCARAB study applied IFM principles to the use of herbicides, fungicides and insecticides, whereas the Lautenbach study applied IFM principles to the use of all agro-chemical inputs, cultivation techniques and the management of non-crop areas (Table 1). It is also clear that the IFM techniques used have changed with time due to the development of new pesticides and changes in government policy. Thus, narrow spectrum insecticides and herbicides have become more widely employed. In addition, the availability of payments for set-aside and for the environmental management of field margins have been important developments for IFM and its impact upon biodiversity.

The reduction in nitrogen fertiliser and pesticides for seven of the studies is described in Table 2. On average, IFM reduced nitrogen use by 18%, herbicide use by 43%, fungicides by 50% and insecticides/molluscicides by 55% compared with conventional management. In general, IFM was found to decrease crop yields slightly, but the effect on net margins was usually slightly positive due to reduction in pesticide and chemical fertiliser costs.

2.2 Literature used

The studies described above have either been written up as project reports for the sponsor or/and written as papers within peer reviewed journals or conferences. Wherever possible, the peer reviewed paper has been used to describe the results of the studies. Additionally, both IFM and non IFM peer reviewed literature has been used to corroborate the findings of the studies. All the literature is catalogued at the end of this report according to different biodiversity categories. The 58 references listed within the LEAF IFM database (www.leafuk.org.uk) as describing biodiversity have also been evaluated (Appendix 2). This shows that relatively few of these references were used in this report because they were either not peer reviewed or did not contain the necessary statistical analyses.

Table 1. A summary of the major IFM projects that have measured biodiversity.

Project title/date	Period of study	Key reference	Plot size	Farm type	Minimum Tillage	Spring crops	Margin/hedge management	Set-aside	Other IFM
Lautenbach Germany	1978-1989	El Titi (1989; 1990)	4 ha	Arable	✔	✔	✔	✕	
Boxworth Project	1981-1988	MAFF (1992)	Field	Arable	✕	✕	✕	✕	
Third way, Switzerland	1981 -	Hani (1989; 1990)	12m x 30m	Mixed	✔	✔	✔	✕	5-10% uncultivated
INTEX, Germany	1989-1997	Wildenhayn (1992) Schmidt & Waldhardt (1992)		Arable	✔		✔	✕	
SCARAB	1989-1996	DEFRA (2001)	Split field	Arable	✕	✕	✕	✕	
TALISMAN	1989-1996	DEFRA (2001)	24m x 4m	Arable	✕	✔	✕	✕	
LIFE	1989-1999	DEFRA (2002; 2003a)	1 ha	Arable	✔	✕	✔	✕	
RISC	1991-2000	DEFRA (2001)	24m x 4m	Arable	✕	✕	✕	✕	
LINK-IFS	1992-1997	Ogilvy (2000)	Split field >2.5 ha	Arable	✔	✔	✕	✔	Csvn headlands Beetle banks
FOFP	1993 -2003	Higginbotham and others. (2000) Saunders (2000)	Split field 4-5 ha	Arable & Mixed	✔	✕	✔	✔	
Rhône-Poulenc	1994-1999	Anon (1997; 1998; 1999) Higginbotham and others (2000)	Blocks 15-20 ha	Arable	✔		✔	✔	Managed uncropped areas

Table 2. Change in pesticide use by IFM compared with conventional management.

Study	Nitrogen	Herbicides	Fungicides	Insecticides/molluscicides
Boxworth	↓ 7% (cost of product)	↓ 50% (cost of product)	↓ 56% (cost of product)	↓ 86% (cost of product)
INTEX	↓ 11% (kg applied)	↓ 71% (spray applications)	↓ 62% (spray applications)	↓ 100% (spray applications)
SCARAB	= (kg applied)	↓ 43% (units applied)	↓ 52% (units applied)	↓ 100% (units applied)
TALISMAN	↓ 50% (kg applied)	↓ 54% (units applied)	↓ 31% (units applied)	↓ 15% (units applied)
IFS-LINK	↓ 20% (kg applied)	↓ 5% (spray applications)	↓ 40% (spray applications)	↓ 40% (spray applications)
LIFE		↓ 32% (a.i. applied)	↓ 79% (a.i. applied)	↓ 69% (a.i. applied)
FOFP		↓ 64% (a.i. applied)	↓ 53% (a.i. applied)	* ↓ 45% (a.i. applied)
Rhône Poulenc		↓ 28% (a.i. applied)	↓ 23% (a.i. applied)	↑ 16% (a.i. applied)
Lautenbach	↓ 21% (kg applied)	All pesticides ↓ 36% (cost of product)		

Unit – recommended dose rate of product; a.i. – active ingredient of pesticide by weight.
* Molluscicides were not reduced in IFM

Table 3. A summary of effects of IFM on biodiversity (↑ - statistically significant increase ($P<0.05$) in biodiversity; = - no significant effects; blank – biodiversity parameter not measured).

Project title/date	Plants/seed bank	Soil microflora/fauna	Arthropods	Earthworms	Birds	Mammals
Lautenbach Germany	↑		↑	↑		
Boxworth Project	↑		↑		=	↑
Third way, Switzerland	↑		↑	↑		
INTEX, Germany	↑					
SCARAB	↑	=↑	=↑	=		
TALISMAN	↑	= nematodes	=↑			
LIFE			=↑	↑		
RISC	↑		=			
LINK-IFS	↑		=	=		
FOFP			↑		↑ =	
Rhône-Poulenc			↑			

3. IFM effects on biodiversity

3.1 Plants and seed banks

IFM was shown to increase the number of non-crop plants or seeds within the soil by each of the eight studies that observed this indicator of biodiversity (Table 3). The plant species that experienced large increases are summarised in Table 4 for some of the studies. The increase in non-crop plants within IFM plots could typically be 35 plants m^{-2} more than in the conventionally managed plots (Ogilvy and others 1996). Many of these are common agricultural weeds and none are included within the vascular plant species list of the Biodiversity Action Plan (BAP). Nonetheless, many of these species provide an important source of food for beneficial arthropods (El Titi 1992; Cowgill and others 1993; Marshall and others 2003) and bird species (Campbell and Cook 1997). The LIFE study attributed the greater number of weeds to minimum tillage, but the weed problems were not economically damaging in this study (Jordan and Donaldson 1996). Whether or not an increase in non-crop plants or seeds was recorded often depended on which area of the field was sampled. For example, the LINK IFS project showed that after five years the seed bank numbers in the field margin at two of the three sites were almost double in IFM plots compared with the conventionally managed plots. However, differences in the field centre were negligible (DEFRA 2000).

Table 4. Non-crop plant species commonly found in IFM

Plant species		**INTEX**	**LIFE**	**TALISMAN**	**SCARAB**
Alopecurus myosuroides	black grass	✔		✔	
Anagallis arvensis	scarlet pimpernel			✔	
Atriplex patula	orache			✔	
Avena fatua	wild oats				✔
Bromus sterilus	sterile brome		✔		
Bilderdykia convolvulus	black bindweed			✔	
Chenopodium album	fat hen			✔	✔
Capsella bursa-pastoris	shepherds purse				✔
Elymus repens	couch		✔		
Galium aparine L.	cleavers	✔	✔	✔	✔
Lamium purpureum	red dead-nettle				✔
Lolium perenne	perennial ryegrass		✔		
Matricaria spp.	mayweed				✔
Myostis arvensis	forget-me-not			✔	
Papaver spp.	poppy		✔	✔	✔
Poa annua	annual meadow grass		✔		✔
Polygonum aviculare	knot grass			✔	✔
Senecio vulgaris	groundsel		✔		
Stellaria media	chickweed				✔
Veronica arvensis	speedwell			✔	✔
Viola arvensis	field pansy		✔		✔

Data from: INTEX - Holland and others (1994); LIFE - Jordan and Donaldson (1996); TALISMAN - Cook (2001); SCARAB - Ogilvy and others (1996).

An increase in the number of plant species was recorded in the Boxworth and TALISMAN studies, but this increase was only statistically significant within the latter study. The TALISMAN study included two types of rotation; a Standard rotation which was predominantly autumn sown crops and an Alternative rotation which was predominantly spring sown crops. These rotations were set up at three sites and were either managed conventionally or using IFM. The IFM reduced herbicides and fertiliser by about 50%. An example of how the populations of the different weed species within the soil seed bank changed during the project at one of the sites is described in Table 5. None of these species appear on the BAP for vascular plants. For the Standard rotation, the seed bank approximately doubled and the number of plant species increased from 8 to 14 during the five year study. This shows how reductions in the number and dosage of herbicide treatments and substantial reductions in nitrogen can be employed in rotations of predominantly autumn sown crops without causing an excessive multiplication of the seed bank. However, a different story was found for the Alternative rotation consisting mainly of spring sown crops. In this rotation, IFM caused the seed bank to increase beyond sustainable levels (Table 5) and the number of plant species increased by 2 or 3 per year over the five year study. The reason for the large difference in weed numbers between the Standard and Alternative rotations appeared to be due to spring sowing *per se* and the use of different crop species.

Table 5. Change of soil seed banks over time and among treatments in TALISMAN at Boxworth (seeds m^{-2}). Standard rotation - mainly autumn sown crops; Alternative rotation – mainly spring sown crops (Squire and others 2001).

Taxa		**1991**	**1996**			
			Standard rotation		**Alternative rotation**	
			Conv.	**IFM**	**Conv.**	**IFM**
Anagallis arvensis	scarlet pimpernel	56	300	600	10,900	39,400
Chenopodium album	fat-hen	56	300	1,200	6,300	20,000
Sinapis arvensis	charlock	0	0	60	1,330	4,220
Alopecurus myosuroides	black-grass	14	330	440	1,060	2,670
Fallopia convolvulus	black-bindweed	14	0	0	610	2,000
Polygonum aviculare	knotgrass	0	0	0	110	1,830
Kickxia spuria	round-leaved fluellen	0	0	60	4,330	1,280
Matricaria spp.	mayweed	0	0	56	170	1,220
Euphorbia spp.	spurge	0	0	0	110	670
Galium aparine	cleavers	0	170	830	560	560
Plantago major	greater plantain	0	0	0	0	560
Stellaria major	chickweed	0	0	110	56	560
Sonchus asper	prickly sow thistle	0	440	170	0	440
Brassica spp.	volunteer oilseed rape	1,320	280	390	220	170
Capsella bursa-pastoris	shepherds purse	14	170	56	56	170
Veronica hederifolia	ivy-leaved speedwell	0	0	110	0	170
Epilobium spp.	willowherb	0	0	0	0	110
Avena sterilis	winter wild oat	0	390	330	170	56
Picris echioides	bristly oxtongue	0	0	0	56	56
Papaver spp.	poppy	0	0	0	110	0
Poa spp.	meadow grass	190	0	56	0	0
Other spp. (6)		70	0	0	0	0
Total		**1,734**	**2,380**	**4,468**	**26,148**	**76,142**

The TALISMAN study also quantified how the size of the seed bank measured in seed m^{-2} (*Sd*) was related to the number of species (*N*) present (Equation 1).

$$N = 8.40\ (\log Sd) - 19.58 \qquad \text{(Equation 1)}$$

This could be a useful method for estimating the change in species number from information about the size of the seed bank.

3.2 Soil microflora/fauna

Soil micro-organisms (bacteria, fungi, viruses and protozoa) form an important living portion of the organic matter content of the soil. They play a vital role in key soil processes such as nutrient cycling, biodecomposition and detoxification of man made compounds such as pesticides. The SCARAB study found that IFM caused a significantly greater biomass of soil microflora at one site, but that it had no effect at another site (Jones and Johnson 2001). At the responsive site, fungicides had a larger effect on soil microflora than insecticides and herbicides. This perhaps is not surprising when it is considered that fungi make up about 70% of the microflora. Fungicides were shown to reduce fungal biomass by 25-50% ($P<0.05$), but the effects were short lived (residual effects were detected up to 55 days after the fungicide application). Similar fungicide effects have been observed by Hart and Brookes (1996). The soil microflora was much less affected by pesticides at the second site of this study (Jones and Johnson 2001). This site had very low levels of soil microflora which may have made the pesticide effects less easy to detect. The low levels of soil microflora may have been caused by the small organic matter content and low moisture content of the sandy soil. This highlights the potential role of site-based factors in determining whether or not IFM increases soil microflora.

The TALISMAN study observed no differences in nematode numbers or the structure of the nematode community when IFM was compared with conventional management (Ellis and others 2001). The most numerous species at all sites was *Helicotylenchus vulgaris* which has a relatively cosmopolitan distribution throughout the UK. A previous study showed that nematodes were reduced by herbicides (Yeates and others (1976), but this was after the repeated use of paraquat which completely removed all potential host plants. TALISMAN detected large differences in nematode populations between sites and years. The reasons for these were unclear, although greater numbers tended to be associated with autumn sown crops (Ellis and others 2001).

3.3 Arthropods

Beneficial arthropods were measured in ten of the eleven studies, with IFM shown to increase numbers in eight of these studies and no increase recorded in two studies (Table 3). These increases were recorded for non-target arthropods. Increases in insect pest numbers, such as aphids, to levels that reduced profit very rare. In the Boxworth and much of the SCARAB studies, the increase in non-target arthropods were attributed to reduced use of broad spectrum organophosphate insecticides in IFM. In 2002, organophosphate insecticides (mainly dimethoate) accounted for only 3% of insecticide use on crops grown in the UK (Garthwaite and others 2002). Therefore, these results are less relevant for current farming practices. This sub-section only considers the effects of pesticides that are commonly used.

The Lautenbach project in Germany recorded significantly more springtails (Collembolae), gasmid mites, ground beetles (Carabidae) and rove beetles (Staphylinidae) in the IFM treatments (El Titi 1995). The Third Way project in Switzerland demonstrated significant increases in Syrphinae, some ground beetle species and Araneae in the IFM plots, which were attributed to greater densities of weed flora within wheat fields and flowering plants in managed field margins (Hani 1989; 1990). The LIFE project observed a significant increase for one species of carabid beetle *Nebria brevicollis* and for money spiders (Linyphiidae) in the IFM treatment (DEFRA 2002). These effects could not be directly attributed to a particular farming practice due to the existence of other confounding factors. A combined analysis of data from the Focus on Farm Practice and Rhône Poulenc studies (Higginbotham and others 2000; Alvarez and others 2001) showed that the integrated plots had 20% more springtails than the conventionally managed plots ($P<0.05$).

Each of the above studies employed minimal cultivation treatments as part of the IFM treatment, which may have contributed to the increased arthropod populations. Holland and Reynolds (2003) recorded fewer total ground beetle species, other coleopteran adults and larvae and Araneae groups emerging from ploughed plots. However, it must be emphasised that some species, such as *Notiophilus bigattus*, were more frequent within ploughed plots. Holland and Luff (2000) also found some ground beetle species to prefer minimal cultivation over ploughing, whereas others exhibited no preference. Kroos and Schaefer (1998) found overall numbers of rove beetle adults to be unaffected by cultivation type, but certain species and total larvae were greater in unploughed plots along with a greater rove beetle species richness. The emergence of sawfly species (Symphyta) has been shown to be reduced by 50% by ploughing (Barker and others 1999). Money spiders have been found to be unaffected by ploughing (Duffey 1978), whereas Blumberg and Crosley (1982) considered them to be very sensitive to tillage. On balance, it seems likely that minimal cultivation will contribute to greater numbers of arthropods observed within the IFM treatments of these studies, but effects will be species dependent.

In the SCARAB study, the IFM treatment significantly increased herbivorous non-target arthropods, but this was consistent in only one field (Frampton 2001). This effect was attributed to inadequate weed control in this field. The SCARAB and TALISMAN studies also observed several significant, but short-lived, reductions in arthropods in the conventional management compared with IFM and attempted to correlate these with individual pesticide applications. The SCARAB study showed that pyrethroids had short-term effects on some species (money spiders, aphids and flies) (Frampton 2001). Springtails, which were very sensitive to organophosphate insecticides (Vickerman 1992), were not affected by pyrethroids and even increased significantly in one conventionally managed field (Frampton 1999). In the TALISMAN study, non-target arthropod numbers were shown to decrease in response to 7 of the 66 insecticide or molluscicide treatments (Ellis and others 2001). Three of these were in response to the molluscicide methiocarb and the others to synthetic pyrethroids and the organophosphate insecticide dimethoate. Methiocarb was associated with reduced ground beetle catches. Dimethoate reduced the number of ground beetles and money spiders, and pyrethroids reduced ground beetles such as *P. melanarius.* The pesticide effects were relatively short-lived, generally lasting three months or less. The TALISMAN study results must be interpreted with care because the small plot size (24m x 24m), even with grass headland buffers between plots, may allowed arthropods to transfer from one treatment to another.

The detrimental effects of methiocarb, dimethoate and pyrethroids on non-target organisms are well known and other studies generally support the SCARAB and TALISMAN findings. For example, the toxcity of methiocarb towards ground beetles was confirmed by Purvis (1992), who showed that recovery of populations did not occur until the following season. Holland and others (2000) showed that dimethoate significantly reduced populations of ground beetle and money spider, with non significant effects on rove beetles and springtails. Moreby and others (2001) compared the effects of dimethoate, synthetic pyrethroids and a carbamate (pirmicarb) on non-target arthropods. Across a wide range of species, this showed that dimethoate was the most toxic and reduced arthropod populations by about 80%, pyrethoids reduced populations by about 60% and pirimicarb reduced populations by about 30% (not significantly different from the control). In contrast to the observations in TALISMAN, in which the effects of pyrethroid insecticides on non-target arthropods were found to be short-lived, Ewald and Aebischer (1999) found that pyrethroids reduced non-target arthropods for more than one year.

The LINK-IFS and RISC studies found no effect of pesticides on non-target arthropods. The LINK-IFS study occasionally observed more invertebrates in the IFM treatment as a result of poor weed control. For example, at one site a greater abundance of *Poa annua* resulted in a two-fold increase in invertebrates in the IFM treatment (Richards and others 1997). Another site was shown to have significantly more predators (ground beetles, rove beetles and money spiders) within the IFM treated winter wheat fields (Holland and Thomas 1997). The IFS-LINK study also found no effect on invertebrates from minimal cultivations.

The Carabidae data from the SCARAB, TALISMAN and LINK-IFS projects has been combined and analysed as part of a DEFRA study (ADAS 1999). Interpretation of the data was often complicated by variation in crop rotations applied at each site in different years. This often resulted in confounding between crop, site and year effects The study showed that site, crop, year and time of sowing were all important in determining the assemblage of species and relative abundance of carabid beetles, but IFM was not significantly different from conventional management. Differences in the relative abundance of carabids were seen for oilseed rape, grass ley, potatoes and to some extent set-aside and barley in comparison with winter wheat, although these were not always consistent between studies. Leys (in SCARAB) and set-aside (in LINK-IFS) favoured mostly autumn-breeding and typical grassland species such as *N. brevicollis* and *B. obtusum*. Spring-breeding Amara species were relatively common in autumn sown oilseed rape, which was surprising as most of these are considered to be species of open, sunny conditions. In comparison with cereals, root crops such as potatoes and sugar beet tended to support an impoverished carabid assemblage, often dominated by one or two species. These crops may provide poor habitats due to the large amount of soil disturbance, late development of ground cover and damaging pesticide use (Holland and others 1996). Spring crops tended to have smaller carabid populations compared with autumn sown crops. The low populations under potatoes and sugar beet may have contributed to this effect. These observations are supported by long term conventional and IFM studies in the Netherlands which showed that crops which provided early ground cover such as winter wheat were most favoured by arthropods (Boojj and Noorlander 1992). Variation in the rate of development of the crop or density of planting may also influence carabid species occurrence. For example, winter barley is known to develop a dense canopy more quickly than winter wheat, which may partly explain the differential abundance of *T. quadristriatus* - a species of open habitats - in winter wheat, compared with *L. pilicornis* - preferring damper habitats - under barley. One of the most important findings of the combined study (ADAS 1999) was the likely importance of time of cultivation for determining both species composition and numbers of carabids.

3.4 Earthworms

IFM resulted in an increase in earthworms in three of the five studies in which these were recorded. The increase appeared to be associated with minimum tillage. The two studies that did not record an increase in earthworms either did not employ minimum tillage in the IFM strategy (SCARAB) or used it only 28 to 56% of the time (LINK-IFS). The LIFE project undertook one of the most comprehensive studies of cultivation type and earthworms (Hutcheon and others 2001; Defra 2003a). From 1990 to 1994, this study used ploughing within the conventional management and non inversion tillage (Dutzi cultivator) in the IFM. From 1995 to 2000, two types of non inversion tillage (Dutzi cultivator and Vaderstad cultivator) were used in the IFM and ploughing continued to be used in the conventional management. Earthworms were sampled in the spring and autumn of each year and classified according to species and age. Averaged over species and age groups, the IFM plots had a significantly greater earthworm biomass than conventionally managed plots after three years (Table 6). The study also showed that the system using the Dutzi cultivator gave much greater biomass increases than the Vaderstad cultivator (Table 7). Earthworm numbers followed a similar trend to overall biomass, but the differences were only significant in 1999 and 2000, when the Dutzi cultivation treated plots had 143 and 155 earthworms m^{-2} compared with 64 to 66 for the conventional plots ($P<0.01$). It was hypothesised that the Dutzi cultivator resulted in a greater earthworm biomass because it significantly increased organic matter content over the Vaderstad system and gave better incorporation of crop residues, which then required fewer secondary tillage operations. Increased organic matter and fewer tillage operations are both known to increase total biomass and number of earthworms (Edwards and Bohlen 1996). The performance of a particular cultivator is dependent on soil type, which may mean that these results cannot be extrapolated to other soils.

Earthworm species differed in their response to farming systems. Numbers of *Al. chlorotica, L. festivus, L. rubellus* and *L. terrestris* were greater in the Dutzi cultivated IFM plots compared with the conventional plots, but *A. calignosa* and *A. rosea* were unaffected by the systems. The remaining species, *A. longa, L. castaneus, O. cyaneum* and *O. tyrtaeum tyrtaeum* also showed no significant response, but in most years these species tended to be more prevalent in the Dutzi cultivator IFM system. It therefore appears that some species are more sensitive to inversion tillage than others. Importantly, this study also showed that the Dutzi cultivation IFM treatment significantly increased the number of earthworm species ($P<0.05$) (as measured using the Shannon index) compared with ploughing.

The importance of type of cultivation for determining earthworm populations was illustrated when the non-inversion IFM plots were ploughed for the first time in 11 years (DEFRA 2003a). This caused the earthworm biomass to decrease from 52 g m^{-2} to 23 g m^{-2} ($P<0.05$). Earthworm biomass then decreased to 17 g m^{-2} after a second year of ploughing, but the plots which reverted to non inversion tillage recorded an increase in earthworm biomass to 32 g m^{-2} ($P<0.05$). This indicates that earthworm numbers can recover quite quickly once non-inversion methods are re-started.

The Lautenbach project which began in 1978 also recorded more earthworms in IFM plots that had been cultivated with a broadshare cultivator compared with conventionally managed plots that had been ploughed. On average between 1980 and 1987, the IFM system recorded 29 earthworms m^{-2} in the IFM treatment compared with 9 m^{-2} in the conventional (El Titi and Ipach 1989; El Titi 1995). The most common species of earthworm in this study was *L. terrestris*.

Table 6. Biomass of earthworms in conventional and IFM treatments between 1990 and 1994. (Data from Hutcheon and others 2001)

Year	Biomass (Ln (g m^{-2}) + 1), with back transformed g m^{-2} in parenthesis	
	Conventional (ploughing)	**IFM-1 (Dutzi cultivator)**
1990	3.71 (39.9)	3.67 (38.3)
1991	3.58 (34.9)	3.83 (45.1)
1992	3.40 (29.0)	3.38 (28.4)
1993	2.63 (12.9)	3.19 (23.3) *
1994	2.85 (16.3)	3.71 (39.9) ***
SED (df)	0.230 (82)	
Mean (all years)	3.23 (24.3)	3.56 (34.2) *
SED (df)	0.149 (17)	

IFM significantly different from conventional * (P<0.05), ** (PP<0.01), *** (P<0.001).

Table 7. Biomass of earthworms in conventional and IFM treatments between 1995 and 2000. (Data from Hutcheon and others 2001)

Year	Biomass (Ln (g m^{-2}) + 1), with back transformed g m^{-2} in parenthesis		
	Conventional (ploughing)	**IFM-2 (Vaderstad cultivator)**	**IFM-3 (Dutzi cultivator)**
1995	2.83 (16.0)	3.52 (32.8) *	3.58 (34.9) **
1996	2.98 (18.7)	3.76 (42.0) **	3.62 (36.3) *
1997	2.87 (16.6)	3.20 (23.5)	3.70 (39.5) **
1998	3.81 (44.2)	3.76 (42.0)	3.95 (50.9)
1999	3.45 (30.5)	3.84 (45.5)	4.23 (67.7) **
2000	3.08 (20.8)	3.52 (20.8)	4.12 (60.6) ***
SED (df)		0.265 (110)	
Mean (all years)	3.17 (22.8)	3.60 (35.6) **	3.87 (46.7) ***
SED (df)		0.158 (18)	

IFM significantly different from conventional * (P<0.05), ** (P<0.01), *** (P<0.001).

The SCARAB and LINK-IFS projects found no significant differences in earthworm numbers or biomass between the conventional and IFS treatments (Ogilvy 2000; Jones and others 2001). This was probably due to the absence or restricted use of minimal tillage as part of the IFM within these studies. SCARAB investigated whether pesticides affected earthworm populations. Large variability was observed for earthworm numbers, but this could not be consistently related with pesticide applications. For example, applications of omethoate, dimethoate, chlorpyrifos and benomyl had no effect on earthworm numbers. Aldicarb did result in dead earthworms on the soil surface during the first few days after application. This effect was believed to be made worse by applying the nematicide to bare soil and was the only time that dead earthworms were recorded. Edwards and Bohlen (1996) listed most organophosphate and pyrethroid insecticides, fungicides (except benomyl and carbendazim) and herbicides as having low toxicity to earthworms, so many of these effects are unsurprising. Toxic pesticides include aldicarb, benomyl, methiocarb, carbofuran and phorate. The greatest variability in earthworm numbers and biomass was observed between sites, with some sites having five times as many earthworms (Ogilvy 2000). One common factor amongst the sites with few earthworms was the inclusion of potatoes in the rotation. It was hypothesised that the high level of soil disturbance associated with these crops may have reduced earthworm numbers.

3.5 Birds

Large experimental units are required to test for differences in bird diversity between management systems. This probably explains why only two studies (Boxworth and Focus on Farm Practice) have assessed birds. The Boxworth study found no consistent effects of IFM on the performance of breeding birds (MAFF 1992). The numbers of skylark *Alauda arvensis*, grey partridge *Perdix perdix*, robin *Erithacus rubecula*, yellow hammer *Emberiza citrinella* and blue tit *Parus cyanus* were recorded within the Focus in Farm Practice study between 1995 and 1997 (Saunders 2000). Skylark numbers were significantly lower on the IFM fields compared with the conventionally managed fields in the first year (6 vs 13), but significantly higher in the third year of the study (56 vs 10). The increase in the third year was attributed to differences in set-aside management and cultivation methods. The IFM set-aside had considerable green cover because clover had been undersown into the previous wheat crop, whereas the conventional set-aside was bare ground. Additionally, the IFM fields were direct drilled compared with ploughing in the conventional management. Over all three years of the study, skylark numbers were not significantly different between the IFM and conventionally managed fields due to the different results observed in years one and three. Over the whole study, skylark numbers were significantly lower on winter wheat and significantly greater in winter beans, set-aside and grass. Numbers of grey partridge, yellow hammer, robin and blue tit were not significantly different between IFM and conventional management, but significantly more grey partridge and yellow hammers were associated with set-aside and break crops such as winter beans. This study concluded that IFM *per se* was not as important as crop production methods, such as the type of cultivation method and rotation cycles such as set-aside and break crops, for affecting bird species. Other studies have also revealed the importance of set-aside for skylarks (Poulsen and others 1998) and grey partridge (Stephen and Aebischer 1992).

The Sustainable Arable Farming For an Improved Environment (SAFFIE) project began in 2002 and aims to investigate conservation practices compatible with profitable production and enhanced biodiversity on arable farms. SAFFIE seeks to achieve this by manipulating vegetation structure. The first experiments have investigated how manipulation of winter wheat crops can affect the breeding of skylarks. The treatments compare: 1) conventional row widths (control), 2) double row widths (25 cm), and 3) winter wheat with two undrilled patches (4m by 4m) per hectare. The experiments are conducted at the field scale at 15 sites in the UK. Results from the first year (Morris and others 2003) showed that the treatment with the undrilled patches had a greater number of territorial males per 5 ha than the control (2.2 vs 1.5), and more nests (1.3 vs 0.8). Both of these effects were statistically significant ($P<0.05$). Other results showed that nestlings per nesting attempt and chick weight in the undrilled patches were not significantly different from the control, which suggests that productivity would not be reduced by the IFM treatment. Wide rows did not provide these benefits. It was hypothesised that the undrilled patches provided a greater food supply because few of the nests were within 10m of the undrilled patches and the foraging period within the areas containing the patches was significantly greater than the control. These differences were more apparent later in the season.

3.6 Mammals

Only the Boxworth study statistically analysed the results of small mammal monitoring (Fletcher and others 1992). This study found that the IFM treatment increased the number of wood mice *Apodemus sylvaticus* at specific times of the year ($P<0.001$). This effect was shown to be caused by the reduced use of methiocarb slug pellets broadcast at the time of cereal sowing. Other studies have shown that wood mice are susceptible to poisoning by methiocarb pellets (Tarrant and Westlake 1988). Across all the years the number of wood mice trapped in October was significantly greater in the IFM fields (57 mice) compared with the conventionally managed fields (27 mice) (Johnston and others 1991). The wood mouse population recovered within 7-27 days due to immigration from other areas. Drilling the slug pellets with the seed greatly reduced the negative effects of methiocarb. This study found no long-term effects of farming system on the population of common shrews.

4. Discussion

The majority of the major IFM studies considered by this report were all arable enterprises, with two mixed farm studies, and no studies on permanent pasture or horticultural enterprises. Arable and grassland each cover about four million ha in England and horticultural production accounts for less than 200,000 ha (DEFRA 2003b). Biodiversity losses have been attributed to conventional grassland management, particularly silage making and the use of high levels of fertiliser (eg Chamberlain and Fuller 2000; Tallowin and Smith 1994). Whilst the horticultural area is much smaller, the lack of information in this area is also significant due to the intense management that many horticultural crops require which could adversely affect biodiversity. There could be scope for IFM on grassland and horticulture to improve biodiversity, but as yet no studies have investigated this. This gap in knowledge must be born in mind when reading the discussion, which is drawn almost entirely from arable farm studies.

This report shows that IFM on arable and mixed farms can increase the biodiversity of plants, soil microflora, non-target arthropods, earthworms, birds and mammals (Table 3). Plant biodiversity was increased the most consistently and none of the studies concluded that there was a negative impact of IFM on any of the biodiversity categories. The majority of the improvements in biodiversity were achieved by increasing the populations of existing species. The exceptions being plant species in one study (Squire and others 2001) and earthworms in another study (Hutcheon and others 2001). However, it is unclear whether each study tested for changes in species number, particularly for plants. The lack of improvement in species number indicates that IFM could simply be increasing the number of existing pests. This was only the case for weeds, which IFM occasionally increased to levels that reduced profit (eg SCARAB). However, it must also be emphasised that many common agricultural weed species provide useful food sources for beneficial arthropods (Marshall and others 2003) and birds (Campbell and Cook 1997). Increases in other types of pest to levels that reduced profit were very rare.

4.1 Effects of specific management practices on biodiversity

Few of the IFM effects on biodiversity have been directly linked with a specific management practice. Those that have include the increase in wood mice in the absence of methiocarb slug pellets (Boxworth study), minimal tillage to increase earthworms (LIFE), the increase in non-target arthropods by reducing insecticides (SCARAB) and the increase in soil microflora by reducing fungicides (SCARAB). It is impossible to attribute more of the biodiversity changes to specific management practices due to the confounding effects of other factors. This problem is inherent within studies that compare entire farming systems. Many of the IFM studies did attempt to attribute some of the biodiversity effects to specific management and supported their hypotheses with peer reviewed literature. We have collated these conclusions in Table 8, together with the statistically significant biodiversity/management linkages described at the beginning of the paragraph, to provide an insight into which IFM management practices may be affecting biodiversity. Improvements in biodiversity appeared to be attributed to the choice of crop (which species and whether it is spring or autumn sown) and minimum cultivations most frequently (Table 8). For example, spring sown crops were associated with more weeds, but were often negatively associated with arthropods, potatoes reduced earthworms, and using a cover crop on set-aside or including break crops favoured birds. Clearly, there is a potential trade-off with the use of spring crops which serves to highlight the difficulty in identifying specific IFM techniques that benefit biodiversity. Minimal cultivation had positive effects on plant, arthropod and earthworm biodiversity. Reduced herbicides and reduced insecticides were the next most important practice (Table 8). The reduced use of slug pellets containing methiocarb was particularly important for improving biodiversity. In 2002, methiocarb was used on 155,000 ha compared with the most commonly used organophosphate insecticide (dimethoate) which was used on 125,000 ha (Garthwaite and others 2003). Reduced nitrogen was expected to improve weed biodiversity by reducing the competitiveness of the crop, but the studies in this report did not detect this effect. This may be because the reduction in nitrogen was generally only 20% or less. Greater reductions in nitrogen would be expected to reduce crop yields and profit.

Table 8. Summary of how IFM practices affected biodiversity.

IFM practice	Plants	Soil microflora	Arthropods	Earthworms	Birds	Mammals
Reduced nitrogen	=	=	=	=	=	=
Reduced herbicides	↑	=	↑ [1]	=	=	=
Reduced fungicides	=	*↑	=	=	=	
Reduced insecticides	=	=	*↑	=	=	*↑ [2]
Minimum cultivation	↑	=	↑	*↑	=	=
Crop type (species/sowing date)	✓ [3]	=	✓ [4]	✓ [5]	✓ [6]	=
Margin management	=	=	↑	=	=	=

* Statistically significant effect ($P<0.05$).
[1] due to more non-crop plant species; [2] due to methiocarb slug pellets; [3] biodiversity increased by spring sowing or altered by crop species; [4] biodiversity increased by autumn sowing or altered by crop species; [5] biodiversity decreased by potatoes; [6] biodiversity increased by spring sowing and set-aside.

4.2 Extrapolation of biodiversity effects to the landscape scale

So far this report has considered the effects of IFM on biodiversity at the scales of plots (24m x 24m), fields and blocks of fields. No studies carried out investigations at a larger scale. The remainder of this discussion considers whether these biodiversity effects could be extrapolated to the landscape scale if IFM practices are employed more widely. It seems likely that the increasing pressure for farmers to trade at low world prices will increase the uptake of IFM techniques. This is because the profitability of IFM increases relative to conventionally managed systems as the price of produce decreases (Jordan and others 2000).

However, it is uncertain whether farmers will embrace the whole concept of IFM as described in the introduction, or whether they will pick and choose specific practices. For example, the range of IFM practices that can be employed may be restricted by the type of environment or economic considerations. On the other hand, the range of IFM practices that are easily employed may expand due to the introduction of agri-environmental schemes. Clearly the impact of IFM on biodiversity depends on which IFM techniques are employed and how widely. This is considered in this sub-section.

Crop type (both species and whether it is sown in spring or autumn) has been identified as a key factor that influences biodiversity. The effects of some crop types on biodiversity can be conflicting, but if farmers follow IFM principles and grow a range of different crop types then the requirements of different types of biodiversity can be met within the farm. However, the introduction of the single farm payment in 2005 reduces the likelihood of farmers growing a diverse range of crops. Shifting subsidies away from specific crops to a flat payment for the farm means that crops are even more likely to be chosen for their profitability in the absence of subsidy. This means that winter wheat and winter oilseed rape will become the crops of choice on most arable farms. Another consequence of the single farm payment, which is less easy to predict, is that more marginal land will be taken out of crop production because it is not profitable. This could increase the area of land under set-aside which would benefit biodiversity.

Predicting the widescale uptake of minimal cultivations is not straight forward because many factors influence its applicability. A recent HGCA review (Davies and Finney 2002) concludes that minimal cultivations can be employed most successfully on stable, well drained soil in dry parts of the country. Light loamy soils are least appropriate because they lead to over compaction. Grass weed pressure will also restrict the frequency with which it can be used, with periodic inversion tillage likely to be necessary. Occasional inversion tillage would certainly reduce earthworm populations, but Hutcheon and others (2001) did show that earthworm populations build up rapidly once minimal cultivations are resumed. Davies and Finney (2002) concluded that most farms should be able to employ minimal cultivations sometimes. Even infrequent use is likely to benefit bird biodiversity and arthropods, but earthworms appear to require several years of uninterrupted minimal cultivations to build up after a prolonged period of inversion tillage (Hutcheon and others 2001).

The reduced use of pesticides is likely to be one of the IFM techniques used. There is evidence that these methods are already being employed by conventionally managed systems because one of the most recent studies (LINK-IFS) had a smaller difference in pesticide use between the IFM and conventional management (Table 2).

The benefits to biodiversity of field margin and non-crop management are well established (Harwood and others 1994; Holland and Thomas 1996; Poulsen and others 1998; Benton and others 2002). However, special management of the field margin and non-crop areas was only used in three of the eight IFM studies carried out in England and few improvements in biodiversity could be attributed directly to this type of management in the studies that employed it. This may have been due to the difficulty of identifying the effect of specific factors within experiments designed to compare farming systems. In future it seems likely that more farmers will manage their margin and non-cropped areas as part of IFM due to the introduction of new Environmental Stewardship Schemes in 2005 (www.defra.gov.uk/erdp/reviews/agrienv). The schemes are likely to include management methods such as buffer strips, beetle banks and over winter stubbles in the Entry Level scheme and wild life seed mixes, minimal cultivations and fallow management in the Higher Level scheme. The employment of this type of management would be expected to enhance the biodiversity benefits of future IFM.

4.3 Gaps and further research required

The most significant gap is the absence of studies that consider the effects of IFM on biodiversity on grassland and horticultural farms. Grassland occupies a larger area in England than arable and intensive production methods have reduced biodiversity on grassland. Horticulture represents a smaller area, but the use of cultivations and crop protection chemicals are intensive for many crops, and IFM offers a way of reducing these which could benefit biodiversity. Therefore research on these types of farm would appear to be of utmost importance to provide a complete understanding of the effects of IFM on biodiversity.

Experiments that are designed to compare entire farming systems are not appropriate for identifying the effect of specific farming practices because of the presence of confounding factors. This was particularly true for the IFM studies reviewed by this report. For example, it was often impossible to identify whether crop species or time of sowing was the key factor affecting weed biodiversity. It was also difficult to prove conclusively that minimal cultivations benefited non-target arthropods. Specific experiments must be designed to identify the key management practices influencing biodiversity. Understanding the effect of individual management practices is very important because of the flexible definition of IFM, which allows different combinations of management to be employed.

Very few studies were able to consider the effects of IFM on birds and small mammals because the scale of the experiments was too small. As a result it is difficult to draw conclusions about these categories. It is expected that the ongoing SAFFIE project will provide information about some aspects of management, such as row width and margin management on birds, but more large-scale experiments will be required to provide a complete picture.

5. Conclusions

Eleven European studies comparing IFM with conventional management have shown that IFM on arable and mixed farms can increase the biodiversity of plants, soil microflora, non-target arthropods, earthworms, birds and small mammals. It is very difficult to attribute the improvements in biodiversity to specific farm management practices due to confounding factors that are present when entire management systems are compared. Minimal cultivations, reduced herbicide and reduced insecticide use appeared to have strong positive effects on biodiversity. Choice of crop species and time of sowing had positive and negative effects. Specially designed experiments are required to confirm the effects of these practices. It seems likely that if IFM is employed more widely, then many of the biodiversity benefits would be extrapolated to the landscape scale. The impact of the Mid Term Review may have a negative and positive influence on this, whilst the introduction of new agri-environmental schemes are likely to enhance the biodiversity benefits of IFM. The most significant gap in knowledge was an absence of IFM studies on grassland and horticultural farms that have recorded biodiversity effects.

6. Reference list

6.1 General references about IFM

ANON. 1997. *Rhône Poulenc Farm Management Study, 7th Annual Report*. Ongar: Rhône-Poulenc Agriculture Ltd.

ANON. 1998. *Rhône Poulenc Farm Management Study, 8th Annual Report*. Ongar: Rhône-Poulenc Agriculture Ltd.

ANON. 1999. *Rhône Poulenc Farm Management Study, 9th Annual Report*. Ongar: Rhône-Poulenc Agriculture Ltd.

ANON. 2001. *Northmoor Trust Conservation Farming Project 1997-2000*. Abingdon: Northmoor Trust.

ANON. 2003. *A Common Codex for Integrated Farming. European Initiative for Sustainable Development in Agriculture (EISA).* EISA, Konstantinstrasse, 90, D-53179, Bonn, Germany.

DEFRA. 2001. Reducing agrochemical use on the arable farm. *In*: J.E.B. YOUNG and others, eds. *The TALISMAN & SCARAB Projects.* London: Defra.

DEFRA. 2002. *Integrated and lower input crop management*. Final Report for Defra.

DEFRA. 2003a. *LIFE, effect of ploughing after non-inversion tillage*. Final Report for Defra.

EL TITI, A. 1989. Research on integrated farming systems at Lautenbach. *IOBC/WPRS Bulletin,* 1989/XII/5, 21-36. Wageningen, The Netherlands.

EL TITI, A. & IPACH, W. 1989. Soil fauna in sustainable agriculture: results of an integrated farming system at Lautenbach, FRG. *Agriculture Ecosystems & Environment*, 27, 561-572.

EL TITI, A. 1990. Farming systems research at Lautenbach, Germany. *Swiss Journal of Agricultural Research,* 29, 237-247.

EL TITI, A. 1992. Integrated farming: an ecological farming approach in European agriculture. *Outlook on Agriculture,* 21, 33-39.

HANI, F. 1989. The Third Way, a research project in ecologically orientated farming systems in Switzerland. *IOBC/WPRS Bulletin* 1989/XII/5, 51-66. Wageningen, The Netherlands.

HANI, F. 1990. Farming Systems research at Ipsach, Switzerland – The 'Third Way' project. *Swiss Journal of Agricultural Science,* 29, 257-271.

HARWOOD, R.W.J. and others. 1994. Managing field margins for hoverflies. *In*: N. BOATMAN, ed. *Field margins: Integrating Agriculture and Conservation,* 147-152. British Crop Protection Monograph 58. Nottngham: Major Print Ltd.

HIGGINBOTHAM, S. and others. 2000. Environmental and ecological aspects of integrated, organic and conventional farming systems. *Aspects of Applied Biology,* 62, 15-20.

HOLLAND, J.M. and others. 1994. Arable acronyms analysed - a review of integrated arable farming systems research in Western Europe. *Annals of Applied Biology*, 125, 399-438.

JORDAN, V.W.L. and others. 2000. The economics of integrated farming systems in the UK. *Aspects of Applied Biology,* 62, 239-244.

MAFF. 1992. Pesticides, Cereal Farming and the Environment. *In*: P. GREIG-SMITH, G., FRAMPTON, G., & T. HARDY, eds. *The Boxworth Project*. London: MAFF.

OGILVY, S.E. 2000. LINK integrated farming systems (a field scale comparison of arable rotations). Volume 1: Experimental work. *HGCA Research Report*, No 173. London: Home-Grown Cereals Authority.

SCHMIDT, W., & WLADHARDT, R. 1992. Geobotanical investigations. *INTEX: Developing an integrated farming system and investigating ecological effects of extensification in arable production-field guide*, 22-23. University of Gottingen, Germany: Research Centre for Agriculture and the Environment.

STOATE, C., & LEAKE, A. 2002. *Where the Birds Sing*. Report for the Allerton Research and Educational Trust/ The Game Conservancy Trust.

WADE, D. 2001. *BEAM – Whole Farm IFS Project. Titley Court Arable Management 2000/2001.* Rosemaund Hereford: ADAS.

WILDENHAYN, M. 1992. INTEX –Ein interdiziplinaires Forschungsvorhaben Entwicklung integrierter Anbausysteme und zur Erfassung okologischer Wirkungen von Extensivierungsmabanahmen. *Mitteilungen der Gesellschaft fur Pflanzen bauwissenschaften* **4**, 37-40. Cited in Holland, and others (1994).

6.2 Weeds and seed banks

COOK, S. 2001. Weed control: the agronomic and economic effects of reducing herbicide use. *In*: J.E.B. YOUNG, and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 63-84. London: Defra.

DEFRA. 2000. *Seed bank dynamics under integrated farming systems*. Final report for Defra.

JORDAN, V.W.L., & DONALDSON, G.V. 1996. Concept and implementation strategies for rotational weed control in non-inversion tillage systems. *Aspects of Applied Biology,* 47, 221-228.

OGILVY, S.E., GREEN, M.R., & MILLS, A.R. 1996. SCARAB – the effects of reduced herbicide inputs on floral density in two arable rotations. *Aspects of Applied Biology,* 47, 211-214.

SQUIRE, G., RODGERS, S., & WRIGHT, G. 2001. The impact of low-input herbicide use on weed seed banks. *In*: J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 86-102. London: Defra

6.3 Soil microflora and fauna

ELLIS, S. and others. 2001. Monitoring the effects of insecticides and molluscicides on non-target arthropods and nematodes. *In* J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 151-174. London: Defra.

JONES, S., & OHNSON, B. 2001. The effects of pesticide regimes on soil microflora. *In*: J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 255-276. London: Defra.

6.4 Arthropods

ADAS. 1999. *Evaluation of species composition and size of carabid beetle populations as indicators of normal field ecosystems*. Report for DEFRA, London.

ALVAREZ, T., FRAMPTON, G.K., & GOULSON, D. 2001. Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. *Agriculture Ecosystems & Environment,* 83, 95-110.

BOOIJ, C.J.H., & NOORLANDER, J. 1992. Farming systems and insect predators. *Agriculture, Ecosystems and Environment,* 40, 125-135.

COWGILL, S.E., WRATTEN, S.D., & SOTHERTON, N.W. 1993. The effect of weeds on the number of hoverfly *Diptera Syrphidae* adults and the distribution and composition of their eggs in winter wheat. *Annals of Applied Biology,* 123, 499-515.

ELLIS, S. and others. 2001. Monitoring the effects of insecticides and molluscicides on non-target arthropods and nematodes. *In*: J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 151-174. London: Defra..

FRAMPTON, G.K. 1999. Spatial variation in non-target effects of the insecticides chlorpyrifos, cypermethrin and pirimicarb on Collembolla in winter wheat. *Pesticide Science,* 55, 875-886.

FRAMPTON, G.K. 2001. The effects of pesticide regimes on non-target arthropods. *In*: J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,* 219-254. London: Defra.

HOLLAND, J.M., & THOMAS, S.R. 1997. Assessing the role of beneficial invertebrates in conventional and IFS during an outbreak of *Sitobion avenae*. *Biological Agriculture and Horticulture,* 15, 73-82.

HOLLAND, J.M. and others. 1996. The LINK-IFS project - the effect of crop rotations and cropping systems on Carabidae. *Aspects of Applied Biology,* 47, 119-126.

RICHARDS, M.C., FISHER, N.M., & DRYSDALE, A.D. 1997. Integrated weed management - its performance over a five-course combinable crop rotation. *Proceedings of the Brighton Crop Protection Conference 1997 - Weeds*, 967-972.

VICKERMAN, G.P. 1992. The effects of different pesticide regimes on the invertebrate fauna of winter wheat. *In*: P. GREIG-SMITH, G. FRAMPTON, & T. HARDY, eds. *Pesticides, Cereal Farming and the Environment. The Boxworth Project,* 82-108. London: HMSO.

6.5 Earthworms

EL TITI, A. 1995. Ecological aspects of integrated farming. *In*: D.M. GLEN, M.P. GREAVES, & H.M. ANDERSON, eds. *Ecology and Integrated Farming Systems*, 243-256. J. Wiley & Sons Ltd.

HUTCHEON, J.A. ILLES, D.R., & KENDALL, D.A. 2001. Earthworm populations in conventional and integrated farming systems in the LIFE project (SW England) in 1990-2000. *Annals of Applied Biology,* 139, 361-372.

JONES, A. and others. 2001. The effects of pesticide regimes on soil microflora. *In*: J.E.B. YOUNG and others, eds. *Reducing Agrochemical Use on the Arable Farm. The TALISMAN & SCARAB Projects,*. 277-286. London: DEFRA.

6.6 Birds

MORRIS, A.J., BRADBURY, R.B., & EVANS, A.D. 2003. Sustainable arable farming for an improved environment: the effects of novel winter wheat sward management on skylarks *Alauda arvensis*. *Proceedings of the Brighton Crop Protection Conference 2003 - Crop Science & Technology*, 227-232.

SAUNDERS, H.J. 2000. Bird species as indicators to assess the impact of integrated crop management on the environment: a comparative study. *Aspects of Applied Biology*, 62, 47-53.

6.7 Mammals

FLETCHER, M.R. and others. 1992. Populations and diet of small rodents and shrews in relation to pesticide usage. *In*: P. GREIG-SMITH, G. FRAMPTON, & T. HARDY, eds. *Pesticides, Cereal Farming and the Environment,* 144-156. London: HMSO.

6.8 IFM literature reviewed and not cited in report

BERGER, H.K. 1990. Effects of alternative soil cultivation and sowing techniques on epigeic fauna. *Swiss Journal of Agricultural Research,* 29, 385-386.

CILGI, T. and others. 1993. The long-term effects of pesticides on beneficial invertebrates – lessons from the Boxworth project. *Pesticide Outlook*, 4, 30-35.

CHAPPLE, D.G., WADE, D.R., & LAVERICK, R.M. 2002. Whole farm integrated management and farmland birds. *Aspects of Applied Biology,* 67, 129-134.

CLEMENTS, D.R., WEISE, S.F., & SWANTON, C.F. 1994. Integrated weed management and weed species diversity. *Phytoprotection,* 75, 1-18.

FRAMPTON, G.K., & CILGI, T. 1993. Long-term effects of pesticides on Carabidae in UK farmland: some initial results from the 'SCARAB' project. *In*: K. DESENDER and others, eds. *Carabid beetles – Ecology and Evolution*, 433-438. Dordrecht: Kluwer Academic Publishers.

HOLLAND, J. 1997. Impact of integrated farming husbandry practices on cereal pests and yield. *Aspects of Applied Biology,* 50, 305-312.

HOLLAND, J.M., FRAMPTON, G.K., & VAN DEN BRINK, P.J. 2002. Carabid beetles as indicators within temperate Arable Farming Systems: Implications from SCARAB and LINK IFM projects. *In*: J.M. HOLLAND, ed. *Agroecology of Carabid Beetles,* 251-270. Andover: Intercept.

JORDAN, V.W.L. and others. 1997. Research into and development of integrated farming systems for less intensive arable crop production 1989-1994. *Agriculture Ecosystems and Environment,* 64, 141-148.

JORDAN, V.W.L. 1998. The development of integrated arable production systems to meet potential economic and environmental requirements. *Outlook on Agriculture Journal,* 27, 145-151.

LITTLE, W. 1998. *Environmental impacts of agriculture*. Report for DETR.

MORRIS, C., HOPKINS, A., & WINTER, M. 2000. *Comparison of the social, economic and environmental effects of organic, ICM and conventional farming*. Countryside and Community Research and IGER.

PACINI, C. and others. 2003. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field scale analysis . *Agriculture Ecosystems & Environment,* 95, 273-288.

VIAUX, P., & RIEU, C. 1995. Integrated farming systems and sustainable agriculture in France. *Proceedings of the Brighton Crop Protection Conference 1995.*

6.9 Non IFM literature cited in report

BARKER, A.M., BROWN, N.J., & REYNOLDS, C.J.M. 1999. o host plant requirements and mortality from soil cultivation determine the distribution of graminivorous sawflies on farmland? *Journal of Applied Ecology,* 36, 271-282.

BENTON, T.G., VICKERY, J.A., & WILSON, D.W. 2002. Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology and Evolution,* 18, 182-188.

BLUMBERG, A.Y., & CROSLEY, D.A. 1982. Comparison of soil surface arthropod populations in conventional tillage, no tillage and old field systems. *Agroecosystems,* 8, 247-253.

CAMPBELL, L.H., & COOKE, A.S. 1997. *The Indirect Effect of Pesticides on Birds*. Peterborough: Cityprint Ltd.

CHAMBERLAIN, B.E., & FULLER, R.J. 2000. Local extinctions and changes in species richness of lowland farmland birds in England and Wales in relation to recent changes in agricultural practice. *Agriculture, Ecosystems and Environment,* 78, 1-17.

DAVIES, D.B., & FINNEY, J.B. 2002. Reduced cultivations for cereals: Research, development and advisory needs under changing economic circumstances. *HGCA Research Review No. 48.* London: Home Grown Cereals Authority.

DEFRA. 2003b. Agricultural and Horticultural Census for England June 1950, June 1970 and June 2000. *Economic and Statistical Analysis*. York: Defra

DUFFEY, E. 1978. Ecological strategies in spiders including some characteristics of species in pioneer and mature habitats. *Symposium of the Zoological Society of London,* 42, 109-123.

EDWARDS, C., & BOHLEN, P.J. 1996. *Biology and Ecology of earthworms.* (3rd Ed.). Chapman & Hall.

EWALD, J.E., & AEBISCHER, N.J. 1999. Pesticide use, avian food resources and bird densities in Sussex. *JNCC Report Series*, No. 296. Peterborough: Joint Nature Conservancy Council.

GARTHWAITE, D.G. and others. 2002. *Pesticide Usage Survey*. DEFRA Report No. 187. London: Department for the Environment Food and Rural Affairs.

HART, M.R., & BROOKES, P.C. 1996. Effects of two ergosterol-inhibiting fungicides on soil ergosterol and microbial biomass. *Soil Biology and Biochemistry,* 28, 885-892.

HOLLAND, J.M., & THOMAS, S.R. 1996. *Phaecelia tanacetifolia* flower strips: their effect on beneficial invertebrates and game bird chick food in an IFS system. *In*: C.J.H. BOOJI, & L.J.M.F. DEN NIJS, eds. *Arthropod natural enemies of arable land,* 171-182. *Acta Jutlandica* 71.

HOLLAND, J.M., & LUFF, M.L. 2000. The effects of agricultural practices on Carabidae in temperate ecosystems. *Integrated pest management reviews,* 5, 105-129.

HOLLAND, J.M., WINDER, L., & PERRY, J.N. 2000. The impact of dimethoate on the spatial distribution of beneficial arthropods in winter wheat. *Annals of Applied Biology,* 136, 93-105.

HOLLAND, J.M., & REYNOLDS, J.M. 2003. The impact of soil cultivation on arthropod (Coleoptera and Araneae) emergence on arable land. *Pedobiologia,* 47, 181-191.

JOHNSON, I.P., FLOWERDEW, J.R., & HARE, R. 1991. Effects of broadcasting and of drilling methiocarb molluscicide pellets on field populations of wood mice *Apodemus sylvaticus*. *Bulletin of Environmental Contamination and Toxicology,* 46, 84-91.

KLEIJN, D., & SUTHERLAND, W.J. 2003. How effective are European agri-environment schemes in conserving and promoting diversity? *Journal of Applied Ecology,* 40, 947-969.

KROOS, S., & SCHAEFER, M. 1998. The effect of different farming systems on epigeic arthropods: a five year study on the rove beetle fauna (Coleoptera: Staphylinidae) of winter wheat. *Agriculture Ecosystems and Environment,* 69, 121-133.

MARSHALL, E.J.P. and others. 2003. The role of weeds in supporting biological diversity within crop fields. *Weed Research,* 43, 77-89.

MOREBY, S.J. and others. 2001. A comparison of the effect of new and established insecticides on non target invertebrates of winter wheat fields. *Environmental Toxicology and Chemistry,* 20, 2243-2254.

POULSEN, J.G., SOTHERTON, N.W., & AEBISCHER, N.J. 1998. Comparative nesting and feeding ecology of skylarks *Alauda arvensis* on arable farmland in southern England with special reference to set-aside. *Journal of Applied Ecology,* 35, 131-147.

PURVIS, G. 1992. A long-term study of the impact of methiocarb molluscide on carabid populations and case history for interpretation of non-target pesticide effects in the field. *Aspects of Applied Biology,* 31, 97-104.

STEPHEN, M.J., & AEBISCHER, N.J. 1992. Invertebrate abundance on cereal fields and set-aside land: implications for wild game bird chicks. *Proceedings of the Brighton Crop Protection Conference 1992, No. 50 Set-aside,* 181-186.

TALLOWIN, J.R.B., & SMITH, R.E.N. 1994. The effects of inorganic fertilisers in flower rich hay meadows on the Somerset Levels. *English Nature Research Reports*, No. 87. Peterborough: English Nature.

TARRANT, K.A., & WESTLAKE, G.A. 1988. Laboratory evaluations of the hazard to wood mice, *Apodemus sylvaticus*, from the agricultural use of methiocarb molluscicide pellets. *Bulletin of Environmental Contamination and Toxicology,* 40, 147-152.

YEATES, G.W.and others. 1976. Long term effects of paraquat-diquat and additional weed control treatments on some physical, biological and respiratory properties of soil previously under grass. *New Zealand Journal of Agricultural Research,* 19, 51-61.

APPENDIX 1 Key biodiversity findings by the major IFM studies

Project title/date	Key biodiversity findings associated with IFM and conventional management comparison.
Lautenbach Germany	Six fold increase in earthworms and increases in Collembola, gamasid mites, Carabidae, Staphylinidae. Identified minimum tillage as important for biodiversity.
Boxworth Project	Designed to test effect of 1970s management, so its pesticide results are less relevant today. Arthropod improvements were linked with absence of organophosphate insecticides. Wood mice improvement associated with absence of methiocarb molluscicides
Third way, Switzerland	More earthworms, Syrphidae, Staphylinidae, parasitic Hymenoptera, Araneae, Entomophthoaceae and some Carabidae species in integrated managed plots. Aphids appeared earlier in IFM, but failed to reach threshold levels.
INTEX, Germany	Showed that animal taxa were affected most by type of cultivation system (similar effects within each system) Weeds were increased where min till and mechanical weeding were used. *Galium aparine* L., *Alopecurus myosuroides* Huds. and *Apera spica-venti* L. increased to levels that undermined sustainability.
SCARAB	Designed to test effect of 1990s management. Arthropod improvements in IFM linked with reduction in broad spectrum insecticides. Effects were transient (a few months). The long term effects at one of eight sites were linked with repeated application of organophosphate insecticides. IFM had negligible effects on earthworms.
TALISMAN	Arthropod analysis was most significantly affected by year and rotation (winter crops vs spring). No evidence that reduced use of herbicides or N affected plant parasitic nematode populations Weed seed bank increased significantly due to IFM. This could be a problem for rotations with spring sown crops. Only 7 out of 66 insecticide and molluscicide applications were associated with a decrease in arthropods and these recovered within 3 months. Three decreases were associated with methiocarb slug pellets Arthropods affected most by year and crop rather than farm system.
RISC	Carabid species diversity was affected by duration and density of crop cover rather than levels of pesticides and fertiliser use. Weed seed numbers increased 14-fold in IFM.

Project title/date	Key biodiversity findings associated with IFM and conventional management comparison.
LIFE	Earthworm benefits associated with minimum tillage. Time of cultivation had no effect. Earthworms decreased by 68% and invertebrates by 20% after IFM plots were ploughed. IFM did not increase arthropod diversity
LINK-IFS	No evidence of any difference in direct impact on beetles, spiders and earthworms between the two systems. Insecticide use was low in conventional system, therefore similar to IFM. Site, season and crop caused large variation in invertebrates. Cultivations did not affect earthworms or invertebrates. Potatoes reduced earthworms and arthropods.
Focus on Farming Practice	Benefits to birds, beetles and earthworms in IFM were attributed to use of minimum tillage which provided more food and shelter
Rhône-Poulenc	Showed that the integrated plots had 20% more springtails than the conventionally managed plots

Appendix 2 The LEAF IFM database

Used in review?	Title	Reference	Findings
No	*A green and pleasant use of land.*	P. Melchet & A. Trewavas. 2002. Article.	Mainly about health but does show that IFM promotes soil biodiversity and bird territories.
No	*A new way for agriculture and the countryside.*	IFM working group. 2002. IACPA.	Cultivation and crop choice more important to biodiversity than crop protection. Little long-term effect on non-target species when pesticides are used according to current practice. Care of margins is crucial for biodiversity. Profitability improves with IFM as grain prices fall.
No	*Agriculture in the United Kingdom.*	MAFF. 1999.	Does not mention IFM directly, but describes uptake of agri-environmental schemes and encouragement of biodiversity.
Yes	Agronomic and environmental implications of soil management practices in IFS.	Jordan, V.W.L., Leake, A.R. and Ogilvy, S. (2000). *Aspects of Applied Biology*, 62.	Improved soil structure and microbial activity. Earthworm biomass increased with minimum tillage. More natural predators recorded.
Yes	Arable acronyms analysed - a review of integrated arable farming systems research in Western Europe.	Holland, J.M., Frampton, G.K., Cilgi, T. and Wratten, S.D. 1994. *Annual Applied Biology,* 125, 399-438.	Review of Boxworth, SCARAB, TALIMAN, RISC, LINK, LIFE & LEAF. Comparison with other European projects. Non-target arthropods and Lumbricidae increased by IFM. This was either caused by reduced pesticide or better habitat due to more weed species, better managed field margins and non-inversion tillage.
No	*Arable Cropping and the Environment - a guide.*	DEFRA/HGCA. 2002.	Describes best practice for IFM and how this may affect biodiversity.
Yes	IFS-LINK Assessing the role of beneficial invertebrates in conventional and IFS during an outbreak of *Sitobion avenae.*	Holland, J.M. and Thomas, S.R.. 1997. *Biological Agriculture and Horticulture*, 15, 73-82.	IFS increases predators, fewer aphids, late aphid outbreak not prevented, greater biological control of insect pests. Aphid predators, parasitoid, aphid resistant varieties and low N inputs all contribute to aphid control.
No	*Biodiversity from concept to business reality.*	Sylvie Marie Lagrange. 2002. Phd Thesis, Wageningen.	Deals with relationship between biodiversity and agricultural activities. Non-cropped area and hedgerows are important.
No	*Business and biodiversity.*	Earthwatch Booklet.	Aim to integrate biodiversity into business thinking.
No	*Buzz project aims to boost farmland biodiversity.*	Farmed Environment Company. 2002. Press release.	3 yr expt to increase biodiversity. Pollen and nectar important. Test different habitats. Mainly concerned with margin management.

Used in review?	Title	Reference	Findings
Yes	carabids as indicators within temperate arable farming systems: implications from SCARAB and LINK IFM projects.	*In*: J.M. Holland, ed. *Agroecology of Carabid Beetles,* 251-270. Andover: Intercept.	Investigates the sensitivity of Carabids to pesticides.
No	Challenging the establishment - tillage stress.	Townsend, S. 2002. *Arable Farming Magazine*, 16 Feb.	Evidence that minimum tillage increases earthworms.
No	*Colworth Farm Sustainable Agriculture Project - Project progress 1999-2000.*	Pendlington, D.J. & van Oostrum, J.W.J. 2001. Report to Unilver.	Assesses which practices affect biodiversity (In progress). High fertility increases weeds.
No	*Comparative impact of insecticide treatments on beneficial invertebrates in conventional and integrated farming systems.*	Holland, J.M. 1998. Eds. P.T. Haskell & P. McEwen. Kluwer Academic publishers.	Uses LINK IFS project. Insecticides were not always the most important factor for invertebrate diversity. Field boundaries and conservation headlands more important than cropped areas. Need more selective products, spray targeting, buffer zones, non-crop areas.
Yes	*Comparison of the social, economic and environmental effects of organic, ICM and conventional farming.*	Morris, C., Hopkins, A. & Winter, M. 2000. Countryside and Community Research and IGER.	A review of many previous systems studies. Chapter 4 compares IFS and conventional.
No	*Conservation Farming Project.*	Northmoor Trust. 2000.	Inputs and practices thought to minimise pollution and habitat loss. Wild life monitored. Encouraging results through targeted pesticide use according to thresholds, use of resistant varieties and encouraging natural predators. IFS sheep system increased several bird species. Mixed system with long or short leys seen as important. Identified Conservation headlands (and nectar rich) as important. Deflectors to prevent N applied to headlands. Low barley yields. No comparison with conventional management.
No	*Conservation pays.*	Frame, J. 2002. British Grassland Society.	Does not describe effects on biodiversity.
No	*Corporate reporting for sustainable development: agriculture.*	Hill, G., Bennett, Ali, Birnie, D., & Crabtree, B. 1999. Macaulay Land Use Research Institute.	Scottish. Little information about biodiversity and IFM.
Yes	*Environmental effects of agriculture.*	Little, W. 1998. Report for DETR.	Summarises several IFS projects. Describes how inputs have decreased and biodiversity has increased.
No	Evidence to support IPM.	Avery, D.T. 1998. *American Outlook* magazine.	Advocates that modern pesticides are used more effectively to minimise effects on wildlife.

Used in review?	Title	Reference	Findings
Yes	Farmland biodiversity: is habitat heterogeneity the key?	Benton, T.G., Vickery, J.A. & Wilson, D.W. 2002. *Report for Trends in Ecology and Evolution*, 18, 182-188.	Habitat diversity increases skylark populations. Non-cropped area is very important. Seed eating birds occur more in grassland areas with small strips of arable than in pure grassland. Management affects species type. Little information on how management affects biodiversity.
No	*Focus on Farming Practice - The case for integrated farm management 1993-2002.*	2002 Report.	Min till contributes to wild life increases by providing food, shelter and reducing soil disturbance. Hedgerow and margin management is key for biodiversity.
No	*Food for Thought - sustainable food production for the 21st century consumer (Boarded barns Study).*	Aventis. 2001. Pamphlet.	Boarded Barns Farm Study. Quantifies input reduction and yields. More shrews due to predator strips and more earthworms due to non-inversion tillage.
No	*How many hectares are cropped under ICM (IPM) in Europe.*	Hewson, R.T. 1999. Isatis Limited for the European Crop Protection Association (ECPA).	States that ICM increases birds and earthworms.
No	*Boarded Barns? - IFM gets best biodiversity results.*	Taverne, D. 2001. Published by Prospect.	Essex study sponsored by Aventis showed that IFM was better than conventional and organic in the environment.
Yes	LINK-IFS Impact of integrated farming husbandry practices on cereal pests and yield.	Holland, J. 1997. *Aspects of Applied Biology*, 50.	LINK-IFS project. Late sowing in IFS can encourage aphid attack due to delayed development, but this also reduced orange blossom midge in some years. Low N may reduce aphids.
No	*Integrated crop management.*	Booklet. 1999. Sponsored by BAA, LEAF and Sainsbury's.	
No	*Integrated crop management systems in the EU.*	Agro CEAS Consulting for European Commission DG Environment (2002).	Results for environmental impact are listed under each site investigated – water, soil, air, biodiversity, landscape.
No	Integrated farming in the Netherlands: flirtation or solid change?	Proost, J. and Matteson, P. 1997. *Outlook on Agriculture*, 26, 87-94.	Limited amount on biodiversity.
Yes	Integrated farming systems and sustainable agriculture in France.	Viaux, P. & Rieu, C. 1995. *BCPC proceedings No 63.*	IFS increases earthworms, but also increased weeds, so plough used 1 year in 4.
No	IACPA report 1998 - Integrated farming systems: the third way for European agriculture?	Morris, C. & Winter, M. 1999. *Land Use Policy*, 16.	States that wildlife is improved through min till and management of habitats.

Used in review?	Title	Reference	Findings
No	*Integrated systems.*	Reading University web page.	Describes how biodiversity has increased in long term projects (more birds). Quantifies yields. Problem with weeds due to non-inversion tillage.
No	Interactions between agricultural emissions to the environment: the value of system studies in minimising all emissions.	Goulding, and others. 1999. Report for Agriculture and Environment – *Challenges and conflicts for the new millenium* – Warwick conference.	Minimum tillage provided a habitat for some bird species, more earthworm species and biomass. These improvements take several years.
No	Killing or culling? Is it possible to manage weeds as a resource?	McRoberts, N. & Hughes, G. 2001. BCPC conference, *Weeds*, 383-390.	Describes how weeds can be managed to improve biodiversity without reducing profit.
No	Less-intensive integrated farming systems for arable crop production and environmental protection.	Jordan, V.W. & Hucheon, J.A. 1993. *The Fertiliser Society Booklet.*	Early results from LIFE.
No	Linking agricultural practice to insect and bird populations: a historical study over three decades.	Benton, T.G. & Bryany, D.M. 2002. *Journal of Applied Ecology*, 39, 673-687.	Bird numbers linked with arthropods and less intensive agriculture. More grey partridge and sawfly larvae in unsprayed fields. . Non-cropped land beneficial.
No	*Mixed farming systems in Europe.*	Ed. H. Van Keulen, E.A. Lantinga & H.H. van Laar. Workshop proceedings from Landbouwuniversiteit, Wageningen. 1998	Nothing on biodiversity.
Yes	LINK-IFS *Phaecelia tanacetifolia* flower strips: their effect on beneficial invertebrates and gamebird chick food in an IFS system.	Holland, J.M. & Thomas, S.R. 1996. Arthropod natural enemies of arable land. *In:* C.J.H. Booji and L.J.M.F. den Nijs, eds. *Acta Jutlandica*, 71, 171-182.	LINK-IFS project. Phaecelia next to wheat crops increased Cereal aphid parasitoids. Some Carabid species favoured wheat crop in preference to Phaecelia. More gamebird chick food in Phaecelia.
No	Professor Trewavas comments on IFM benefits.	*Farmers Guardian*. 2002.	Bird territories, earthworms and soil invertebrates increase.
No	*Progress towards Integrated arable farming research in Western Europe.*	Holland, J.M. 1994. Report for Pesticide Outlook.	Review of LIFE, LINK-IFS and other European studies. Weeds, invertebrates, earthworms increase. Reasons suggested.

Used in review?	Title	Reference	Findings
Yes	LIFE - Research into and development of integrated farming systems for less intensive arable crop production 1989-1994.	Jordan, and others. 1997. *Agriculture Ecosystems and Environment*, 64, 141-148	Summarises yields, input reductions and increases in natural predators.
No	*Restoring confidence in farming - the role of integrated systems.*	Farmer conference. 1998. IACPA	Nothing on biodiversity.
No	*Sustainable agriculture and rural development.*	Report for United Nations Environment and Development UK committee. 1995.	Lists the benefits from increased biodiversity. Apparently all these benefits can be achieved under IFM. No hints that it relates biodiversity with farm practice.
Yes	*Sustainable arable farming for an Improved Environment (SAFFIE).*	www. Saffie.info	New management approaches for habitats through crop and non-cropped margin, eg wide spaced rows and patches. Different grass mixtures will also be assessed. Effect on profits and biodiversity will be evaluated.
No	Taking a LEAF out of the environmental book.	*The Scotsman* Newspaper article. 2002.	Used grass strips to reduce diffuse pollution from sprayers. Partidges and yellow hammers increased.
No	The development of integrated arable production systems to meet potential economic and environmental requirements.	Jordan, V.W.L. 1998. *Outlook on Agriculture* Journal.	Min Till encourages natural predators. Increased earthworms, spiders, carabids. Quantifies input reductions.
Yes	The effects of agricultural practices on Carabidae in temperate agro-ecosystems.	Holland, J..M. & Luff, M.L. 2000. *Integrated pest management review,* 5, 109-129.	Non-crop habitats such as hedges, field margins are important for carabidae predators. Over wintering sites for breeding also important. Can manipulate these sites.
Yes	The impact on non-target arthropods of integrated compared to conventional farming.	Holland, and others. 1998. *BCPC pests and diseases*.	Spring and non-cereal crops especially potatoes least favoured by Carabidae and Linyphiidae. Some natural predators favour weedy crops. Must exploit natural predators fully to see a beneficial effect.
	The 'Less intensive farming and environment' project (LIFE).	DC Bradley as part of a review of ICM systems in EU. Published by CEAS. 2002.	Earthworm populations greater in IFS over 10 year period. More polyphagus predators in autumn sown crops.
Yes	The LIFE project Long Ashton 1989-2003.	IACR. 2002.	Earthworm biomass increased by 38% in IFM.
Yes	The LINK-IFS project - the effect of crop rotations and cropping systems on Carabidae.	Holland, and others. 1996. *Aspects of Applied Biology*, 47.	Min Till encourages Carabids. Potatoes reduced Carabids due to soil disturbance and use of insecticides. Crop type, spring vs winter sowing, level of weed control and insecticides all affect Carabids.

Used in review?	Title	Reference	Findings
No	*The Manor Farm project.*	Report for the farmed Environment Company. 2002.	Set up in 1998. Set-aside managed to increase arable weeds, pollen and nectar sources. Breeding bird territories increased by 30% between 1999 and 2001. Type of invertebrate is very dependent on mixture of plants in the margin. More butterflies due to grassy margins. Ground beetles prefer cropped areas over margins. Red clover important to bumble bees. Voles prefer wide margins, wood mice colonise habitat centres in the middle of fields. IFM – caused increase in ground beetles. No comparison with conventional.
No	*The state of the UK's birds.*	Annual Report for RSPB. 2001.	Nothing about IFS
No	*The Strategy for Sustainable Farming and Food - Facing the future.*	DEFRA report. 2002.	Nothing specific on how IFS affects biodiversity.
No	Wheat growers hear soil erosion warning.	Colin Stride, *Farming News*, 21 June 2001	Minimum tillage increases earthworms.
No	*Where the birds sing.*	Stoate, C. & Leake, A. 2002. Report for the Allerton Research and educational Trust/ The Game Conservancy Trust.	Describes how set-aside can be used to create habitat diversity without reducing profit. Strips of set-aside used. Kale good for seed production. IFM – used an Airtec sprayer to minimise spray drift, min till, hedge maintenance under countryside stewardship, wide margins provide nesting habitats and increases natural predators (helped by less pesticides). Headlands managed to remove pernicious weeds and the same headland is not used for conservation in successive years. Broad spectrum insecticides avoided. Min Till increases soil invertebrates which provide food for birds. No comparison with conventional management.
No	www.scientists-for-labour.org.uk	Website. 2003.	Document that supports IFM. No mention of Biodiversity.

ENGLISH NATURE

English Nature is the Government agency that champions the conservation of wildlife and geology throughout England.

This is one of a range of publications published by:
External Relations Team
English Nature
Northminster House
Peterborough PE1 1UA

www.english-nature.org.uk

Cover printed on Character Express, post consumer waste paper, ECF.

ISSN 0967-876X

Cover designed and printed by Status Design & Advertising, 2M, 5M, 5M.

Front cover photographs:
Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888

CHARTER MARK
Awarded for excellence