SESSION 3B

CROP MANAGEMENT FOR FARMLAND BIODIVERSITY

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Papers:	3B-1 to 3B-5

What biodiversity should we expect from farmland?

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ABSTRACT

Agricultural land-use is a major influence on global biodiversity. The greatest declines in biodiversity have occurred in areas where the intensity of agriculture is high. Conversely, in less intense areas, biodiversity declines have been less or not seen. It is crucial that farming and biodiversity are integrated, so future agriculture policy decisions hold the key to the fate of our farmland biodiversity. This paper reviews the current status of biodiversity on cropped land in Europe using bird populations as an indicator, the current importance to biodiversity of this land, and an assessment of future threats and opportunities.

BIODIVERSITY AND AGRICULTURE – THE NEED TO INTEGRATE

Traditional conservation of our global biodiversity has been the establishment of a network of reserves and national parks. This method has characterised the conservation efforts of, for example, countries in North America. Here an ethos has predominated that outside such protected zones, areas are not viewed as places for wildlife to live. In contrast, the relative small land mass of European countries such as the UK means land has to fulfil a number of roles for society, not just that which some see as its primary function. This means that European biodiversity conservation is inextricably linked with all land and all uses.

Within Europe, agriculture accounts for 130 million hectares (OECD, 2003) and the total conservation interest of farmed land may exceed that of protected areas (Krebs *et al.* 1999). Agricultural activities have both beneficial and harmful effects on the environment through changing the quality and quantity of soil, water, air, natural habitats, biodiversity and landscapes. Biodiversity can be affected through the replacement of natural habitats and the subsequent management regimes.

AGRICULTURE – A CHANGING HABITAT

Key factors in determining the biodiversity 'carrying capacity' of any land-use are the diversity and quality of habitats it holds (Newton 1998). Agriculture has shaped the land for centuries, and since Neolithic times, farming has gradually changed natural and semi-natural habitats, allowing much of the wildlife to adapt, exploit and sometimes become dependent on the new habitats created (Pain & Dixon, 1997). However, in the past thirty years, the types and speed of change in agricultural practice, collectively described as 'intensification', has been widespread and rapid [reviewed in Chamberlain *et al.* (2000)]. These changes, aimed at maximising the proportion of primary production available for human consumption (Krebs *et al.* 1999), include the development of hardier crop varieties, enhanced efficiency of farm machinery, and greater use of, and more effective, agrochemicals. All these factors within crop production systems have contributed to our ability to more than double wheat yields in the UK since 1950 (Fuller, 1999). The consequence of this achievement has been a marked degradation in the biodiversity value of the cropped area.

INDICATORS OF CHANGE

A wide range of farmland taxa has undergone marked population declines and/or range contractions (plants, Rich & Woodruff, 1996; invertebrates, Wilson *et al.*, 1999; birds, Fuller *et al.*, 1995; and mammals, Flowerdew, 1997). However, when assessing the health of the whole ecosystem and the impacts of changing land-use it is impractical to undertake autecological studies for all species. Instead, the relative suitability of species and taxa as indicators of the complexity of factors influencing habitat quality have been examined (e.g. flora Wilson *et al.*, 2003; e.g. invertebrates Andersen *et al.*, 2002; e.g. birds Furness & Greenwood, 1993).

Whilst invertebrate and plant populations respond rapidly to habitat change, problems of scale, cost and expertise make detailed information on their distributions and population changes more difficult to collect (Pain & Dixon, 1997). Conversely, birds are often less sensitive to habitat quality changes so populations may respond after a time lag. Despite this, birds have been widely used as bio-indicators as comparatively with other taxa, their ecological needs and responses to habitat change has been extremely well studied, plus fairly good data is known regarding their distribution, numbers and historic population trends (Tucker & Heath, 1994).

BIRD TRENDS IN THE UNITED KINGDOM

Bird populations in the UK have been one of the most studied across the world with long-term monitoring programme of abundance in existence since 1961. The ability to track UK breeding bird population changes annually, has provided the UK Government with a key indicator of sustainability (Gregory *et al.*, 2002; Figure 1). Underlying the fluctuations in the overall wild-bird indicator, many species associated with farmland habitats have not fared well.

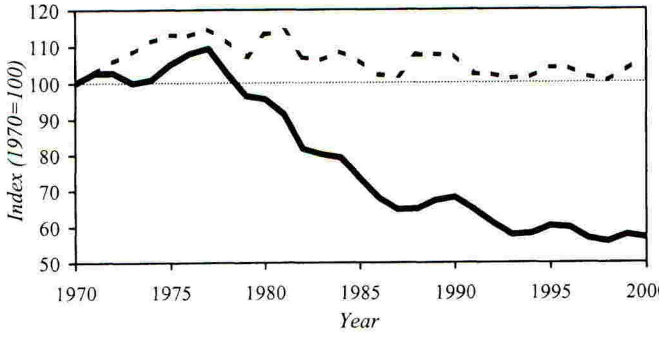

Figure 1. Population trends of UK breeding birds used by the UK Government as a 'Quality of Life' indicator. Broken line denotes all bird species (over 500 breeding pairs) across all habitats (105 species). Solid black line denotes farmland bird specialists (19 species) (Gregory *et al.*, 2002).

Table 1. Percentage population change (1970-2000) and ecological requirements of the 19 farmland bird 'specialists' contributing to the UK Government's Quality of Life Indicator (in Figure 1) (Gregory *et al.*, 2002; Aebischer *et al.*, 2003)

† Nest site: G = ground; Hd = hedgerow or ditch; T = tree: Food: I = invertebrates, S = seeds; V = vertebrates; F = foliage. ++ = primary requirement; + = requirement

Species	% change	Ecological requirements from farmland†								
		Nest site			Summer food			Winter food		
		G	Hd	T	I	S	V	I	S	F
Tree sparrow *Passer montanus*	– 95			++	++				++	
Corn bunting *Miliaria calandra*	– 92	++			++	+			++	
Grey partridge *Perdix perdix*	– 86	+	++		+	+				
Turtle dove *Streptopelia turtur*	– 72		++			+				
Starling *Sturnus vulgaris*	– 69			++	++			++		
Yellow wagtail *Motacilla flava*	– 53	++			++					
Yellowhammer *Emberiza citrinella*	– 49				++	+			++	
Skylark *Alauda arvensis*	– 48	++			++	+			+	+
Reed bunting *Emberiza schoeniculus*	– 48		++		++			+	++	
Lapwing *Vanellus vanellus*	– 47	++			++					
Linnet *Carduelis cannabina*	– 42		++			+			++	
Rook *Corvus frugilegus*	– 37			++	++					
Kestrel *Falco tinnunculus*	– 6			++	+					
Whitethroat *Sylvia communis*	+ 15		++		++					
Greenfinch *Carduelis chloris*	+ 24		+	+	+	+			++	
Goldfinch *Carduelis carduelis*	+ 39		+	+	+	+			++	
Woodpigeon *Columba palumbus*	+ 54			++	++	++			++	+
Jackdaw *Corvus monedula*	+ 114			++	+	+		+	++	
Stock dove *Columba oenas*	+ 143			++		+			+	+

Since monitoring began, whilst a few bird species associated with farmland appear to flourish under the intense cropping systems, for example, carrion crow (*Corvus corone*) and woodpigeon (*Columba palumbus*) (Tucker, 1997), many have been in severe long-term decline and/or range contractions over this relatively short time period (Gregory *et al.*, 2002; Table 1). Considerable weight of scientific evidence implicate agricultural intensification as the driving force for these population changes including autecological studies, for example grey partridge (*Perdix perdix*) Potts (1986), and the temporal and spatial correlation between these sustained declines and agricultural intensification (Fuller *et al.*, 1995). On average, farmland specialists (namely, those species which either nest in fields or rely substantially on fields to provide their food; Table 1) have undergone larger contractions in range than species associated with other habitats and a higher proportion have declined compared to habitat generalists which have tended to increase (Fuller, 1999).

BIRD TRENDS ACROSS EUROPE

Lowland farmland across Europe supports more bird Species of European Conservation Concern (120) than any other habitat (Tucker & Heath, 1994). Those factors implicated in the decline of many UK species are regarded as having had a deleterious impact on European populations. Donald, Green & Heath (2001) demonstrated that the extent of farmland bird population declines and/or range contractions within each country reflected the difference in agricultural intensity, and declines in the European Union (EU) have been greater than in non-Member States (Figure 2).

Until recently, geo-politically Europe could be divided into those countries within the European Union (EU15[1]) and those outside (including ten accession countries[2]). Accession will turn the EU15 into the EU25, with potentially has major implications for the biodiversity within the 10 countries wishing to join. Agricultural production in these countries is expected to expand after accession as a response to factors such as high and stable prices (OECD, 2003). Agriculture across many of the accession countries is far more extensive than in the EU15 and retains many valuable agricultural habitats requiring low intensity agriculture (Donald *et al.*, 2001).

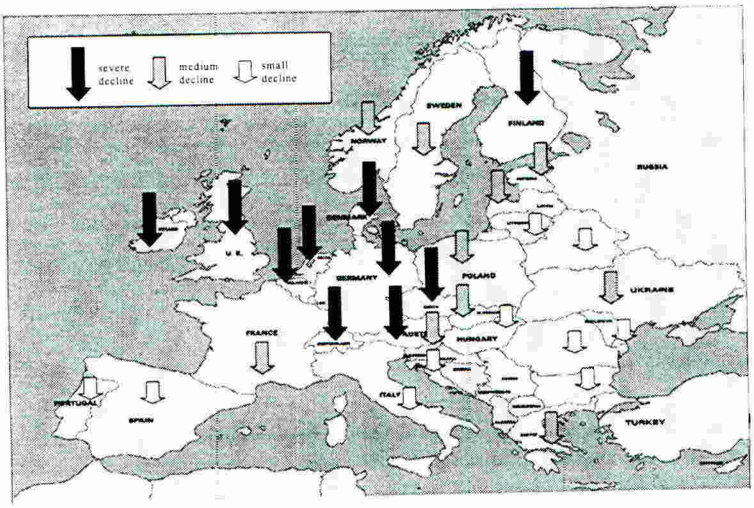

Figure 2. Population trends of wild birds on agricultural land across Europe linked to agricultural intensification (after Donald *et al.*, 2001).

OTHER FARMLAND TAXA

Invertebrates

Studies of farmland invertebrate populations have traditionally focused on species as agricultural pests, pollinating, predatory and parasitic insects or insects as food for birds (e.g. Foster *et al.*, 1997; Wilson *et al.*, 1999). Long-term data sets have identified declines in various invertebrate groups resulting from changing agricultural practice (Ewald & Aebischer, 1999). Most notably, declines in groups such Araneae, Lepidoptera and Chrysomelidie have been associated with increased insecticide use on farmland (Ewald & Aebischer, 1999). Another key factor influencing invertebrates has been the disappearance of undersowing of cereals to create a ley as intensive farming regimes have specialised their operations, as many species benefit from no cultivations over winter.

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[1] EU15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, The Netherlands, Portugal, Spain, Sweden, United Kingdom.

[2] Accession countries: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia

Flora
Intensive arable systems across North-West Europe have seen a decline in some arable flora such as cornflower (*Centurea cyanus*) whilst invasive species such as cleavers (*Galium aparine*) have become more prominent. Various studies have implicated agricultural intensification in these changes: (i) temporal comparative studies in Central Europe have highlighted botanical declines under intensive farm management (Andreasen *et al*., 1996); (ii) botanical diversity is greater where intensive farming practices are avoided (Moreby *et al*., 1994); (iii) field scale experimental studies demonstrating the effects of particular components of agricultural intensification, such as fertiliser application levels (Green, 1990).

Mammals
Harris *et al*. (1995) highlighted that 38% (14 of 36) mammal species associated with UK farmland were believed to be declining. The brown hare (*Lepus europaeus*) is a species which has been particularly affected by changes in agricultural practice, formerly considered abundant, substantial declines since the early 1960s has been observed (www.ukbap.org.uk). Agricultural impacts are likely to have been the increased use of farm machinery (leveret mortality), direct and indirect mortality from herbicide use, increased field sizes, and the reduction of habitat diversity causing an inconsistent food supply throughout the year (Flowerdew, 1997).

OPPORTUNITIES AND THREATS TO BIODIVERSITY

Agriculture will continue to evolve. Greater emphasis on sustainability, political agendas, technological advances, and farmer/consumer attitudes are just some of the factors which will drive agriculture and its biodiversity 'carrying capacity'. Within Europe, the Common Agricultural Policy (CAP) is likely to remain, at least in the medium term, the political tool through which these, sometimes contradictory, factors are addressed. In June 2003, the EU announced plans to reform the CAP resulting in considerable flexibility for Member States. Whilst some countries may see radical change, in others the status quo will be retained. Given this current uncertainty of implementation, we have concentrated on what we feel are the key elements of how European agriculture may change and some of the possible opportunities and threats for biodiversity.

By far the biggest threat to European biodiversity is accession. The new member states will add about 38 million hectares of Utilised Agricultural Area to the 130 million hectares of the EU15 (OECD, 2003). If in response to joining the EU, farmers using low-intensity regimes move to intensify their production systems, then biodiversity is likely to decline rapidly. This would mirror the experiences of countries such as the UK, where the pace and extent of intensification increased in 1973, when the country joined the EU (Chamberlain *et al*., 2000).

Since its inception, the CAP has been dominated by production-linked support. The opportunity to completely decouple these payments from production could be positive or negative for biodiversity, through changing land use patterns. For example, a positive impact may be lower intensity systems or new habitat creation on marginal land where arable cropping was only previously viable through direct production support payments. Conversely, in core arable areas where yields are higher, further intensification would further degrade the biodiversity value of this land. This may be ameliorated by cross-compliance, linking the receipt of support payments to maintenance of land in good agricultural and environmental condition. Although primarily targeted at preventing abandonment in marginal areas, if appropriately set, it can ensure that any further intensification of arable areas is not in contravention with existing EU legislation. Equally, through increased awareness of responsibilities and the threat of increased financial penalties, cross compliance can provide an important baseline for biodiversity protection, upon which biodiversity enhancement through agri-environment schemes can be built.

The agri-environment regulation (EU 2078/92) sets out to provide a mechanism by which biodiversity, and other environmental objectives, could be met. Uptake varies across the EU, for example, 78% of Austrian farmers participating whilst only c. 7% of Spanish farmers (www.europa.eu.int/comm/eurostat). However, the key for biodiversity delivery on farmland is not merely a function of participation, but scheme design also. Until recently, countries with developed schemes which have concentrated on targeted prescriptions to protect and/or recreate valuable habitats. This approach has delivered considerable benefits for species such as cirl bunting (*Emberiza cirlus*) which require weedy stubble fields to provide winter food and rough grassland areas for summer food in close proximity (Peach *et al.*, 2001). Recently, in countries like England, there is increasing recognition of the need to complement this approach with a lower level, broad-scale approach to conserve widespread, yet declining, species such as skylark (*Alauda arvensis*) and linnet (*Carduelis cannabina*). The new Entry Level Scheme, currently being piloted in England, offers a real opportunity through minor adjustments in farming practice to improve the carrying capacity of farmland for biodiversity on a country-wide scale.

A current national '*environmental*' scheme, by default, is set-aside. Introduced as a surplus control mechanism, it has been shown to be potentially of environmental benefit, though this is strongly dependent on its form (non-rotational or rotational) and its subsequent management. These areas removed from production can provide an abundance of volunteers, biennials, grasses, annual weeds and perennial herbs (Vickery & Fuller, 1998), plus greater breeding densities of birds such as skylark than winter cereals (Wilson *et al.*, 1996). However, set-aside cannot be relied upon to deliver long-term benefits for biodiversity given that its area will be determined by the market so consequently will rise and fall irrespective of the needs of wildlife. Whilst it remains, the key is retaining flexibility of management and form if its biodiversity benefits are to be maximised.

Genetic modification of crops, particularly herbicide tolerant (GMHT) is currently the focus of a great deal of attention with regard to their potential impact on farmland biodiversity. The ability to use broad-spectrum herbicides on tolerant crops offers growers new weed control strategies largely unavailable under conventional regimes. Retention of non-crop flora (and thus associated fauna) under such regimes will determine the biodiversity impact of this new technology. Although using a simple model, Watkinson *et al.* (2000) illustrated the potential for this technology to exacerbate biodiversity decline through removal of a non-crop plant, fat hen (*Chenopodium album*), on which skylarks feed.

CONCLUSIONS

In Europe, two key challenges face conservationists, farmers and politicians regarding what our farmland should deliver in terms of biodiversity. The first is to halt and reverse the declines seen in some countries; the second is to safeguard areas of high biodiversity value so emergency remedial measures are not required in the future. Recent policy reforms have put in motion a change in the way support is provided in some sectors. Expansion in funding towards the development and refinement of agri-environment schemes offer the opportunity to integrate biodiversity and farming systems. In countries where biodiversity losses have already occurred, this needs to be coupled with expanded research programmes identifying acceptable solutions of real conservation value. Whilst the key to safeguarding the natural heritage of accession countries will be ensuring that the payments farmers receive are subject to meaningful cross compliance measures which protect the environment alongside country-specific agri-environment schemes to provide incentives for enhancement.

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Weeds: their impact and value in arable ecosystems

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ABSTRACT

Traditionally, farmers have viewed weeds as competitors with current and future crops, affecting yields and quality, and so should be eliminated, as far as possible, from fields. In contrast, weeds also offer food and shelter to invertebrates and birds and thus are significant contributors to the health of the arable ecosystem. As the environmental role of farming becomes increasingly significant, is it possible to combine both adequate weed control to retain crop performance with delivery of environmental benefits? This paper compares the competitive impact of different weed species in winter wheat with their role as food sources for birds and invertebrates. These comparisons indicate species that are not tolerable within fields (because of their competitive impact) and species of lesser effect on the crop that deliver environmental value. Is it possible to develop crop management that retains the latter, whilst minimising the former?

INTRODUCTION

The role of weeds in arable ecosystems is changing. The headlong drive towards maximising crop yields initiated in the 1950's, as a response to food shortages in the previous decade, was so successful that the European Union has a surplus of many commodity products. Concerns about the overall impact of crop production on the environment, and of the use of pesticides in particular, have increased over the last 15 years. Over the last few years, it has become generally accepted that farming practices have had a negative effect on diversity in arable ecosystems. This is demonstrated by declines in farmland birds (Siriwardena *et al.*, 1998) and plants (Sutcliffe & Kay, 2000; Preston *et al.*, 2002). The current philosophy of the UK government is that protection and stewardship of the rural environment is as important as food production. The Government's policy document published at the end of 2002 'Working with the grain of nature: a biodiversity strategy for England' emphasises this issue more strongly. It states that biodiversity is a fundamental consideration in agriculture and that they should be:

‘encouraging the management of farming and agricultural land so as to conserve and enhance biodiversity as part of the Government’s sustainable food and farming strategy’ (www.defra.gov.uk/wildlife-countryside/ewd/biostrat/index.htm). Thus, arable farming from a governmental viewpoint has to deliver biodiversity value as well as food!

The government has set various environmental ‘Biodiversity Action Plan’ (BAP) targets, a number of which relate to farmland birds, as indicators of the ‘health’ of the farming ecosystem (www.ukbap.org.uk). It must be remembered that over 70% of the UK land area is farmed (arable, grassland, forestry) and so the indigenous flora and fauna has to coexist with man. We do not have the luxury of compartmentalising the country into areas for food production and areas for wildlife as can happen, for example, in N. America. Government policy is to increase agricultural support through environmentally-oriented payments and to decrease production subsidies. Some of this environmental support relates to the management of weeds as it is argued that a more diverse arable flora could enhance invertebrate and bird numbers, thus meeting a number of the government’s BAP targets. There is some evidence that the decline in weeds (wild plants) in and around arable fields as a result of changes in agricultural practices over the last 30years, has contributed to this decline in diversity (Ewald & Aebischer, 1999). Consequently, there is increasing pressure on arable farming to reduce the intensity of weed management either on whole fields or parts of fields (e.g. headlands).

All the issues raised in the previous paragraph contrast with the traditional attitude to weeds, which considered them as crop competitors and potential contaminants, to be eliminated from fields. Farmers have been endeavouring to achieve this by cultural methods and rotations for many centuries, and with herbicides for more than 50 years. This has not happened but it is certainly true that the numbers of some arable weeds and their seedbanks have declined over the last 30 years (Preston *et al.*, 2002; Marshall *et al.*, 2003). These changes can be attributed to changes in cropping patterns (spring to autumn cropping; mixed farming to arable monocultures) and in production systems but changes in weed control have also had an impact. Farmers still continue to aim for weed eradication, especially where aggressive, competitive weeds such as *Alopecurus myosuroides* (black-grass), *Avena fatua* (wild-oats) or *Galium aparine* (cleavers) dominate the flora. This highlights the crux of the dilemma of conflicting interests (how to avoid yield loss from weeds whilst delivering biodiversity improvements to arable ecosystems). The paper by Boatman *et al.*, (2003) begins to establish how a regulatory approach could be developed to this subject, whilst this paper reflects on some of the issues relating to weeds. Specifically, it will identify the weeds that are thought to be of value to invertebrates and birds and will then balance this with assessment of their competitive impact and thus ‘acceptability’ to farming. It will focus on ‘in field’ species rather than those that occur in field margins and hedgerows as the management dilemma is less acute with the latter.

THE VALUE OF WEED SPECIES TO BIRDS

Farmland birds may eat weed seeds or may feed on invertebrates that live on the weeds, or may require both. The majority of farmland bird species feed their chicks on invertebrates, whilst the adults of most species feed on seeds and in some cases other plant material, especially in the winter. There are two periods of the year when the availability of food is critical, the winter, and the early summer, when the birds are raising chicks. So the presence of weeds or weed seeds at these times is especially important. Research over the last 10 years has explored the diet of birds. Some of this work is based on faecal studies and some on observations of feeding preferences. A recent review by Marshall *et al.*, (2001, 2003) has collated this information and it provides a basis for beginning to identify which plant species are favoured as food for farmland birds. It is clear from this work that the genera *Stellaria, Chenopodium and Polygonum* are particularly important, along with *Cerastium, Sinapis, Viola, Poa*, *Rumex* and *Senecio* (Table 1). This immediately gives clues as to which are the most useful weed species for birds. However, care is needed in adopting this approach. Whilst some species are important in the diet of a number of bird species, a few are particularly important for a single species. An example is *Fumaria* spp., the seeds of which are particularly important in the diet of the turtle dove (*Streptopelia turtur*) (Murton *et al.*, 1964), but is not generally eaten by other species.

How many seeds are needed and where? How selective are the different bird species? Do related plant species within a genus differ in 'attractiveness'? Work is in progress to answer to these questions.

Table 1. The importance of families and genera of common weed species in farmland bird diet. (from Marshall *et al.*, 2003)

Very Important[1]	Important[2]	Present[3]	Nominally Present[4]
Family			
Poaceae	Compositae	Boraginaceae	Papaveraceae
Polygonaceae	Labiatae	Euphorbiaceae	Primulaceae
Chenopodiaceae	Boraginaceae	Solanaceae	Umbelliferae
Caryophyllaceae	Violaceae	Fumariaceae	
Cruciferae		Scrophulariaceae	
		Geraniaceae	
		Rubiaceae	
Genus			
Stellaria	*Cerastium*	*Sonchus*	*Euphorbia*
Chenopodium	*Sinapis*	*Centaurea*	*Galeopsis*
Polygonum	*Viola*	*Capsella*	*Lamium*
	Poa	*Cirsium*	*Matricaria*
	Rumex	*Fumaria*	*Myosotis*
	Senecio	*Spergula*	*Avena*
			Bromus
			Galium
			Geranium

1. Family: comprises > 5% diet of 12 or more of 33 seed-eating farmland bird species. Genus: comprises >5% diet of 9 or more species
2. Family: as for 1, between 3 and 11 bird species, Genus: as for 1, between 3 and 7 bird species
3. Family: as for 1, 1-2 bird species. Genus: as for 1, 1-2 bird species
4. Present in diets of some species, but <5% on average.

THE VALUE OF WEED SPECIES TO INVERTEBRATES

The relationships between weeds and invertebrates have been explored by both weed scientists interested in predation of seeds and by entomologists exploring the host range of invertebrates. The latter work has been summarised in the report by Marshall *et al.* (2001). The results of surveys of host preferences of a wide range of invertebrates to a number of major UK weeds are presented in Table 2.

Table 2. Numbers of phytophagous insects associated with selected weed species, derived for the Phytophagous-Insect Database. Data are numbers of insect families, species, host-specific insect species and pest species recorded on particular weeds. (from Marshall *et al.*, 2003)

Weed species	*No. insect Families*	*No. of insect species*	*No. of host-specific species*	*No. pest species*
Aethusa cynapium	4	4	0	0
Alopecurus myosuroides	2	6	0	2
Anagallis arvensis	3	3	0	0
Avena fatua	3	5	1	0
Anisantha sterilis	4	4	2	0
Capsella bursa-pastoris	5	13	2	3
Cerastium fontanum	13	22	1	0
Chenopodium album	15	31	2	3
Cirsium arvense	19	50	5 (1)	4
Euphorbia helioscopia	4	5	0	1
Fumaria officinalis	1	3	0	0
Galeopsis tetrahit	6	13	1	0
Galium aparine	13	30	4	4
Geranium dissectum	2	2	0	0
Lamium purpureum	8	18	2 (1)	1
Matricaria recutita	9	15	1 (1)	1
Myosotis arvensis	3	3	0	0
Papaver rhoeas	7	8	0	2
Persicaria maculosa	9	20	1	1
Poa annua	15	53	7 (3)	4
Polygonum aviculare	15	61	4 (2)	3
Rumex obtusifolius	15	79	4	1
Senecio vulgaris	10	46	4	3
Sinapis arvensis	13	37	3	13
Solanum nigrum	3	7	0 (1)	2
Sonchus oleraceus	14	28	1 (1)	1
Spergula arvensis	4	8	0	1
Stellaria media	12	71	4	3
Tripleurospermum inodorum	15	31	3 (2)	4
Veronica persica	1	1	0	0
Viola arvensis	2	2	0	0

(Number in brackets = No. Red List insect species)

It is clear that some species are more favoured by invertebrates than others. Thus, some of the more noxious weed species such as the grass weeds *A. myosuroides* and *A. fatua* have little value for invertebrates. Interestingly, the species with least recorded insect families and species, *V. persica*, is a Neophyte to the UK flora being first recorded in 1826 (Preston *et al., 2002*). It seems not yet to have acquired an associated fauna! Conversely, some of the less aggressive weeds, such as *Cerastium fontanum, Stellaria media* and *Poa annua* are visited by a range of invertebrate species. Indeed, some of the invertebrate species, including those that feed in the flowers and developing fruits, feed on only a narrow range of plant species and are therefore of high potential biodiversity value themselves.

The second area of research related to the association between weeds and invertebrates is the work on seed predation. Many of the seeds shed by weeds may be eaten by vertebrates and invertebrates (Westermann *et al.*, 2002; Lutman *et al.*, 2002; Watson *et al.*, 2003). This is a key, but poorly understood, aspect of the population dynamics of weeds. Recent experiments have shown that seed predation can be high in arable ecosystems. Predation clearly has an impact on the population dynamics of the weeds and investigative research is beginning to demonstrate which groups of vertebrates and invertebrates benefit from the presence of weeds. The published work shows that birds (often pigeons), mice and carabid beetles are the main predators. Their relative importance depends on seed size, time of availability, and location. The structure of the habitat, influenced greatly by weeds, is also of critical importance to invertebrates. It is important to realise that only selected groups of carabids feed on seeds, whilst others are omnivorous and will take both invertebrates and seeds. The relative importance of the seeds from the less competitive weed species in the diet of the most abundant carabids in arable ecosystems is currently being investigated in cafeteria-style experiments. In addition, we do not yet know the impact of slugs on seed populations. This is also an area currently being investigated by the authors.

In assessing the potential value of weed species in the context of biodiversity, we also need to consider those species that may harbour insect pests (see Table 2). It is also true that the recorders that provided the information for the Phytophagous-Insect Database may have overlooked some of the less competitive weed species with a less conspicuous stature.

THE COMPETITIVE IMPACT OF WEEDS

Weed species vary in the impact that they have on crops. Their effects also vary between crops, especially when comparing spring and autumn-sown ones. Research over the last 10 years has endeavoured to quantify their relative competitive effects in winter wheat. Most of the values presented in Table 3 are based on the results of field trials but a minority are based on expert opinion. Clearly, some species are predicted to be much more damaging than others. These values are being tested in current field trials. A further list is in preparation for spring cereals, where it is likely that primarily spring emerging species such as *C. album* will have a much higher rating. It must also be remembered that climatic conditions, particularly rainfall, can change the competitive impact of the weeds. For example, wet summers result in greater competition from *Galium aparine,* because the weed's shallow rooting system makes it very vulnerable to summer drought. Current modelling studies are endeavouring to include an element of stochasticity in the predictions of the competitive effects of weeds. However, despite this variability these competitive abilities do provide a basis for ranking the relative effects of different species

Table 3. Relative competitive abilities of common weeds in winter cereals (values are weed densities (plants/m^2) to cause a 5% yield loss) (from Cussans *et al.*, unpubl. data)

Weed species	5% Yield loss (plants/m^2)	Weed species	5% Yield loss (plants/m^2)
Alopecurus myosuroides	12.5	*Geranium spp.*	62.5
Anisantha sterilis	5.0	*Lamium purpureum*	62.5
Avena fatua	5.0	*Legousia hybrida*	250.0
Lolium multiflorium	8.3	*Myosotis arvensis*	25.0
Poa annua	50.0	*Papaver spp*	16.7
Aethusa cynapium	83.3	*Polygonum aviculare*	50.0
Allium vineale	250.0	*Persicaria maculosa*	25.0
Anagallis arvensis	100.0	*Ranunculus spp.*	62.5
Aphanes arvensis	250.0	*Senecio vulgare*	83.3
Brassica napus	12.5	*Silene vulgaris*	25.0
Chenopodium album	25.0	*Sinapis arvensis*	12.5
Cirsium spp	16.7	*Sonchus spp*	50.0
Convolvulus arvensis	16.7	*Stellaria media*	25.0
Epilobium spp.	50.0	*Taraxacum officinale*	50.0
Fallopia convolvulus	16.7	*Tripleurospermum inodorum*	12.5
Fumaria officinalis	62.5	*Veronica spp*	62.5
Galium aparine	1.7	*Viola arvensis*	250.0

OVERALL REATIONSHIP BETWEEN COMPETITIVE EFFECTS AND BENEFITS FOR BIRDS AND INVERTEBRATES

The final component of the selection of weed species that could be considered by farmers to be retained in fields or in margins and headlands, is to link the beneficial species in Tables 1 & 2 to the detrimental ones in Table 3. Thus, weeds can be selected from Table 4 and allocated to the following categories:

a) not tolerable weeds with little biodiversity value e.g. *A. fatua, A. myosuroides*
b) less competitive and value for diversity, e.g. *S. media, Polygonum* spp. (in w.wheat)
c) not tolerable but of some biodiversity value e.g. *G. aparine, Cirsium* spp.
d) less competitive, and of little diversity value e.g. *M. arvensis, Veronica* spp.

This information can then be used to begin to develop strategies for weed management that minimise the risks from the competitive species, whilst retaining the diversity value of the less damaging ones. Such selective management could be applied to whole fields but it might be more appropriate to consider implementation on headlands and field margins. In these 'edge' areas crop yield and quality is generally lower, weed diversity and abundance tends to be higher (Marshall, 1989), and many (though not all) bird species prefer to feed (Vickery *et al.*, 1998). Appropriate selection of herbicides and doses could achieve this selective weed management.

One of the options in the UK's environmental enhancement scheme, Countryside Stewardship, is to selectively manage wild plants in field margins, but at the moment is rather restrictive in its permitted herbicide options. Work is in progress in several current Defra-funded projects to develop approaches that deliver environmental benefits without having a major impact on crop production. It is not easy to achieve these aims because of shortage of information on the diversity value of some species, lack of 'tools' to achieve selective weed removal, and annual weather induced variation in the competitive impact of weeds, but progress is being made. The LINK project 'Weed Management Support System' (Collings *et al.*, 2003) aims to create a decision support system for weeds and will provide a mechanism whereby the issues raised in this paper could be delivered to farmers and advisors. The prototype version of the DSS already highlights weed species of value for biodiversity and the herbicide package can select products that will selectively control some weeds and not others.

Table 4. Ranking of the competitive effects of selected weed species and their value for birds and invertebrates. (* ** *** refers to their increasing importance for birds/inverts or increasing competitive impact, '-' = no importance, blank = no information)

Species	Comp. index	Value for birds	Value for insects	Species	Comp. index	Value for birds	Value for insects
Alopecurus myosuroides	***		-	*Geranium spp.*	**		-
Avena fatua	****	-	-	*Lamium purpureum*	**	-	**
Lolium multiflorium	****			*Legousia hybrida*	*		
Poa annua	**	**	***	*Myosotis arvensis*	**	-	-
Aethusa cynapium	**		-	*Papaver spp*	***		*
Anagallis arvensis	*		-	*Persicaria maculosa*	**	***	**
Aphanes arvensis	*			*Polygonum aviculare*	**	***	***
Brassica napus	***	**	-	*Ranunculus spp.*	**		
Chenopodium album	**	***	***	*Senecio vulgare*	**	**	***
Cirsium spp	***	*	***	*Sinapis arvensis*	***	**	***
Convolvulus arvensis	***			*Sonchus spp*	**	*	***
Epilobium spp.	**			*Stellaria media*	**	***	***
Fallopia convolvulus	*	***		*Tripleurospermum inodorum*	***		***
Fumaria officinalis	**	*	-	*Veronica spp*	**		-
Galium aparine	****	-	***	*Viola arvensis*	*	**	-

NB five letter codes for weeds equate to species list in Table 3

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Sustainable arable farming for an improved environment: the effects of novel winter wheat sward management on Skylarks (*Alauda arvensis*)

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ABSTRACT

Sustainable Arable Farming For an Improved Environment (SAFFIE) is a large Sustainable Arable LINK consortium project, testing solutions for delivery of biodiversity within winter-cereal dominated farmland. As part of the experimental programme, the sward structure of winter wheat crops is manipulated, to enhance late-summer access to nest-sites and food for a ground-nesting bird; the skylark (*Alauda arvensis*). This experiment runs over 2002-3, with three field-scale 'treatments' on at least 10 sites in each year. The treatments compare (i) conventional winter wheat, (2) winter wheat sown in double-normal (25cm) row widths, and (3) winter wheat with two 4m by 4m 'undrilled patches' per hectare. The effects of the three treatments on skylark distribution and breeding performance in the breeding season of 2002 are presented. Indications from 2002 suggest that the creation of undrilled patches may help to extend the breeding season of the skylark in winter wheat crops, by providing additional nesting and, particularly, feeding sites. This will be further evaluated in 2003.

INTRODUCTION

In 2002, winter wheat crops were grown on over 1.8 million hectares of English farmland, representing 48% of the cropped and fallow land area. In some regions, particularly where soil conditions mean that spring cultivation is regarded as high risk, winter wheat may comprise an even greater proportion of the cropping. For example, in Cambridgeshire, winter wheat accounts for 55% of the cropped area and 87% of cereal crops (<3.5% of which are spring sown) (Anon., 2002).

There is mounting evidence that the structure of winter wheat results in a relatively poor breeding and foraging habitat for crop-nesting birds, such as the skylark (*Alauda arvensis*). Research has shown that skylarks prefer vegetation less than 50 cm in height for nesting and less than 25cm in height for foraging. It is also likely that the abundance of weed and invertebrate food is low compared with other habitats (Donald, in press; Wilson, 2001). Winter cereals represent a sub-optimal habitat for skylarks, as after the first few weeks of the breeding season (which historically extended from the start of April until August) their tall, dense structure limits access for both nesting and feeding. Donald (in press) cites a curtailment of the breeding season in arable crops as one of the main reasons for decline in UK skylark abundance (-55%) over the last 25 years.

The UK government's Department for Environment, Food & Rural Affairs has a Public Service Agreement to reverse the decline in a suite of farmland bird species, including the skylark, by 2020, and a Biodiversity Action Plan target to increase the area of cereal field margin under conservation management. At the same time, UK growers are under strong economic pressure to optimise inputs and improve efficiency. In order to meet these often conflicting objectives, the five-year Sustainable Arable LINK collaborative project, Sustainable Arable Farming For an Improved Environment (SAFFIE), involves stakeholders from NGOs, industry and government, seeking to develop a balance of farming and allied conservation practices compatible with profitable production and enhanced biodiversity. SAFFIE seeks to achieve this by manipulating vegetation architecture (including bare ground, sward height, structural and species diversity) in: (a) the crop (years 2002-2003); (b) the field margins (years 2002-2006); and (c) the integrated effects of both 'best' crop and margin management (years 2004-2006). To this end, SAFFIE monitors several bird species, the abundance and availability of invertebrate and weed food resources and includes a cost benefit analysis. See www.saffie.info for more details.

More specifically, one of the aims of SAFFIE is to reverse the curtailment of the skylark-nesting season by providing more open winter wheat. This paper discusses the effects of manipulating crop architecture on skylark distribution and breeding performance in 2002.

METHODS

Sites

Experimental manipulations of crop architecture run over two years, with three field-scale 'treatments' at 15 sites (situated in N. & E. Yorkshire, Norfolk, Suffolk, Cambridgeshire, Bedfordshire, Oxfordshire and Wiltshire) in 2002. The treatments compare: (1) conventional winter wheat (control), (2) winter wheat sown in wide-spaced rows (WSR) at double-normal widths (c.25cm), and (3) winter wheat with two 'undrilled patches' (UP) per hectare. The patches are approximately 4m by 4m in size, and are created by turning off the seed drill temporarily. All treatments (including the undrilled areas) are managed in the same manner, to best Integrated Crop Management practice.

Fieldwork

Between the start of April and mid August, RSPB fieldworkers conducted visual observations to obtain data on numbers of skylark territories (counts of singing males) and foraging locations. All foraging visits to the nest field and surrounding habitats were recorded during one to three nest watches (each lasting 60-90 minutes), once nestlings were aged ≥2 days old. Through visual observations (including the carrying of nest-material or food and behaviour indicating the presence of incubating females), 99 skylark nests were located on the SAFFIE treatments (33 on controls, 52 on UP and 15 on WSR), yielding data on nestling body-condition, partial brood loss and nest productivity. These were measured using standard techniques (Donald, *et al.*, 2001, 2002).

Data analysis

General Linear Mixed Modelling (GLMM) procedures in GENSTAT 5 were used in the analyses. All modelling used step-up procedures to achieve a minimum adequate model (MAM) at the $P = 0.05$ level and specified 'site' as a random effect. Variations in the numbers of territories and nests per hectare were modelled with Poisson errors and log-link functions. Nest failure rates (using field means to control for non-independence of nests in same field, with number of nest failures per field as the response variable and total exposure days of all nests as the binomial denominator) and foraging patterns (with number of forages within nest field as the response and total number of forages - within & outside of the nest field - from the nest as the binomial denominator) were modelled with binomial errors and a logit link. Nestling condition was modelled using normal errors and identity link, following the methods of Bradbury *et al.* (2003). Nest productivity figures were calculated following the method of Donald *et al.* (2002).

RESULTS

Territory Density

Numbers of Skylark territories (singing males) varied significantly with both treatment type and month (Table 1). Over the whole breeding period, the mean number of singing males was greatest on UP treatments, while WSR treatments supported fewer males than the controls. On all treatments, the number of territorial males decreased later in the summer. On UP the decrease was not as pronounced as on the other treatments, with territory density in June equivalent to that on controls in April.

Table 1. Number of territorial males/5ha - GLMM MAM

Term	*Wald*	df	*P*	Back-transformed Means – no. territories
Treatment:	17.37	2	<0.001	
control				1.528
patches				2.167
WSR				1.179
Period:	8.14	1	0.004	
April				1.849
June				1.340

Nest numbers

As not all territorial birds attempt to breed later in the season (Donald, *in press*) the number of nesting attempts may be a better measure of the value of the treatments. Skylark nest numbers per field varied significantly with both treatment and period (Table 2).

Table 2. Numbers of nests per treatment (adjusted for treatment size) - GLMM MAM. *Period* (Early nests: 1st egg date <18 May; Late nests: 1st egg date > 24 May

Term	*Wald*	df	*P*	Back-transformed means - no. of nests
Period:	6.78	1	0.009	
early				1.1423
late				0.5725
Treatment:	6.27	2	0.044	
control				0.8038
patches				1.2942
WSR				0.5084

Over the whole breeding period, the number of nests was greatest on UP treatments, while WSR treatments supported fewer nests than even the controls. On all treatments, the number of nests decreased later in the summer (Figure 1), but the decrease on UP was 30% compared with 64% on controls.

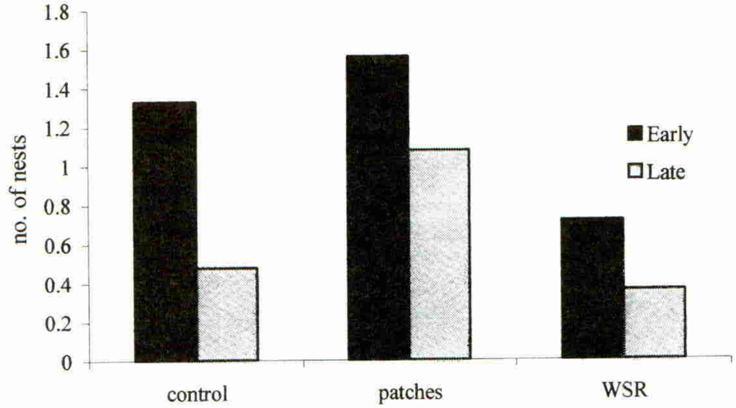

Figure 1. Mean number of nests per treatment (adjusted for size) from GLMM

Productivity

In some agricultural habitats, e.g. non-rotational set-aside, a greater density of nests may not equate to greater overall productivity, as survival is poor. Indeed Donald *et al.* (2002) found that productivity per nesting attempt in cereals (mean 1.2 chicks per attempt) was greater than in other crop types. Productivity figures in SAFFIE treatments early in the breeding season were similar to this estimate. However, later in the breeding season UP nests produced an average of one more chick per attempt than those in controls. Productivity in WSR was also high, although the sample was too small to divide by period (Table 3).

Table 3. Productivity per nesting attempt. Overall nest survival rate calculated by raising daily survival rate to power 22 – the average duration (1st egg – nestlings leaving nest) in days of a successful skylark breeding-attempt. Nestlings per attempt calculated by - *overall nest survival rate * % nestling survival * (mean clutch size * % eggs hatched)*

treatment & period	No. nests	Daily failure rate	overall nest survival rate	mean clutch size	% eggs hatched	% nestling mortality (excl. whole-brood failure)	nestlings per attempt
control - early	16	0.033	0.478	3.25	84.62	3.23	1.272
control - late	8	0.045	0.363	3.40	76.19	7.69	0.868
patch - early	21	0.031	0.500	3.53	81.13	8.70	1.308
patch - late	18	0.015	0.717	4.00	75.00	13.64	1.858
WSR – all nests	13	0.007	0.857	3.43	62.50	15.00	1.784

Nestling condition

If SAFFIE can deliver a greater number of nesting attempts and enhanced productivity, this would be a major contribution to the skylark population, provided nestlings survive to breed in subsequent years. Assessment of potential recruitment into the breeding stock remains difficult, as some factors, such as post-fledging and over-winter survival rates, are not known. However, body mass of nestlings immediately prior to leaving the nest is known to be a significant predictor of post-fledging survival in many species. Individually, neither SAFFIE treatment nor period had a significant effect on body mass. However, the interaction between treatment and period was significant. After controlling for nestling age, body mass decreased in the controls but increased in UP and WSR over the course of the breeding season (Table 4). Such a relationship suggests that, in the novel treatments, nestling food was more abundant, more accessible to foraging birds, or of better nutritional quality.

Table 4. Nestling condition - GLMM MAM. Field means used to control for non-independence of nesting attempts in same field. To control for differences in brood age, mean tarsus length (covariate) was forced into model and only measurements from broods aged 5-7 days were included. *Brood size* (covariate) was also included in the full model but not retained in the MAM. *Period* (as for nest analysis)

Term	*F*	df	*P*	Back-transformed field mean nestling mass (g)		
tarsus	180.18	1	<0.001			
period	0.06	1	0.801			
treatment	0.92	2	0.411			
period.treatment	4.02	2	0.029		early	late
				control	18.17	15.14
				patches	16.34	18.17
				WSR	17.45	18.88

Foraging patterns

Treatment and the interaction between treatment and period both had significant effects on the ratio of foraging within and outside of the nest field (Table 5).

Table 5. Foraging - GLMM MAM. *Period* (as for nest analysis)

Term	*F*	df	*P*	Back-transformed proportion of foraging within treatment		
period	1.32	1	0.251			
Treatment:	18.24	2	<0.001			
control				0.784		
patches				0.961		
WSR				0.350		
period.treatment	14.85	2	<0.001		early	late
				control	0.929	0.503
				patches	0.956	0.965
				WSR	0.190	0.554

The proportion of within-treatment foraging flights decreased over time in control fields, indicating they were becoming less suitable for foraging, but remained constant in UP. Results for WSR treatments should be treated with caution, as sample sizes are very small.

DISCUSSION

Based on the results from 2002, it seems that the UP treatments may confer significant advantages for skylarks over conventionally-managed winter wheat. As hypothesised, benefits are most apparent for later nesting birds, an indication that provision of patches may enable more pairs to breed for longer. In later UP nests, the maintenance of a high proportion of within-field foraging and better nestling body condition than in the controls, plus the fact that few nests (4 out of 52) in the UP treatments were situated in or close to (<10m) of the patches, suggest the main benefit of patches probably lies not as nesting habitat but as foraging areas. Further data collection is being undertaken during the summer of 2003 to provide a more detailed study of the use of the patches by foraging skylarks and other bird species.

Currently, it is uncertain whether WSR are beneficial to skylarks. Only small numbers of nests were located in this treatment in 2002. However, the nest survival rate was high.

Treatment block positions were re-randomised for the 2003 breeding-season, to ensure that the results obtained in 2002 were not attributable to treatment location. Analysis of these data will take place over the coming months.

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Meeting the margins – for profit – for biodiversity

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ABSTRACT

Farmers are increasingly being driven down the road of environmental delivery and compliance and this paper will highlight the financial implications and concerns that farmers are facing. There are many drivers for farmers to adopt environmental measures. These include personal desires and priorities, seeking differentiated market opportunities, to secure financial support payments and cost management efficiencies. This paper will show how farmland practices are changing through whole farm planning techniques, through engaging and communicating to the general public through farm visits and in the market place on the retailer shelf. Farming is changing and the sound management of biodiversity can fit well within any farming system and need not compromise business performance. There are many win-win situations and there are many practical examples that can be given to demonstrate more efficient use of resources across the farm to deliver profit and biodiversity.

INTRODUCTION

The White Paper, Our Countryside: the Future (Defra, 2003) sets out governments vision for the countryside, which includes rural communities which are diverse, economically and environmentally viable and inclusive, with high-class public services and real opportunities for everyone. The Haskins Rural Task Force, proposed that farming policies should make better links with the wider community. In particular, he stressed, rural tourism is seen as a powerful economic resource, frequently worth more economically than farming. It is critical that as an industry we are prepared for the next 20 years.

The priority for farming is to deliver more customer focused, competitive and sustainable farming and food. Farming needs to focus on the priorities of a more effective food chain ensuring that a greater proportion of food sales returns to the farmer. With the aim to influence the global market of the food chain, enhance the environment through farming, invest in people and knowledge for the long term and achieve healthy communities. A tall order, so how can it be put into practice? While it is evident that economic instruments and incentive payments and support payments will be critical in making this happen in the shorter term.

What will also be important is to ensure that farming practices are moving forward, to directly address these issues and priorities in a balanced and focused way. This is where whole farm planning is an important area and systems, such as Integrated Farm Management (IFM) can add substantial benefit.

What is critical is the need to focus on the following key areas, understanding:

- the importance of drivers for environmental compliance
- the way to encourage people to change practices
- the need to assess this change of practice
- the market place and how to influence
- the development of environmental and economic practices

Work by the ilu in Germany (ilu, 1999) identified that IFM can be seen as a system component that offers the best potential to be an integral part of an overall sustainable agricultural system (FIL). The Reform of Common Agricultural Policy (CAP) 2000 highlighted agriculture's multifunctionality, in terms of economic, ecological and social measures and this has been further emphasised with more recent changes in the 2003 CAP reform. IFM offers the means to achieve the flexibility needed to assist farmers in practically and realistically balancing these objectives. In particular studies, over Europe (Agra CEAS, 2002) incorporating crop rotations, integrated pest and fertiliser management are recognised as important steps towards sustainable development objectives. This is where the framework of IFM can help in that it acknowledges that the environment should not be counted as a free good but an asset to be looked after. All farming activities have ecological and economic effects that must also be taken into account either through support or the market place. Good quality food is taken for granted in the West and high standards of animal welfare and environmentally acceptable land management are growing demand areas.

DRIVERS FOR CHANGE

Throughout history farming and food production has been fashioned by many drivers for change. In more recent years from the days of the Irish famine to today, a food crisis in the Western world constitutes an empty shelf in a supermarket on a Friday night. Economics, self-satisfaction, caring for the environment, incentive payments, the market place and peer pressure are drivers for change. A recent survey carried out by Deloitte and Touche, and the Royal Agricultural Society of England (RASE) (Deloitte & Touche, RASE, 2003) focused on the need for benchmarks of the future. It paid particular attention to the demands now facing many farmers. In effect there is a new breed of farmer emerging: the manager, the entrepreneur, the environmentalist and the communicator, all these tasks and demands, creating a divergence from the core business and opportunities. The result identified that in many instances, larger farms have more time and more resources to invest in training, environmental schemes and off farm opportunities. All farmers face many increased demands on their time as they become more accountable in order to reassure their customer.

This study is further backed up by the research on IFM and its potential uptake in the UK (Park *et al.*, 1997) that highlighted IFM does require skill and time in its management but this is rewarded in environmental benefits and continuing economic sustainability. IFM offers a system that focuses on doing something the right way for the right reasons. This attention to detail reduces costs and improves efficiency. Furthermore since IFM is a whole farm approach it is the diversity and dynamic approach that is flexible enough to meet the multi-faceted demands of the farmer.

PROFIT

Change is the only constant in today's agricultural industry, and there is little opportunity for many farmers to cut costs much further. Increased profits must therefore come from increasing sales value as well as or indeed, just as much as controlling costs.

Competitive agriculture needs to be achieved through making agriculture more environmentally sustainable at the same time as remaining profitable. Environmental benefits cannot be left out of the farming equation. Farming must be part of a community approach to protect and enhance our landscape. This is backed up by a strong recognition of farmers needing to be rewarded for being environmentally sensitive. Value not just achieved through commodities but also contributed through social and environmental benefits. (Wildlife and Countryside Link, 1998)

MARKET

Marketing is an area where farmers can gain improved prices and value. The Deloitte Touche/RASE survey showed 56% of respondents achieved a premium price of at least 30% of their output. However, unless marketing is acknowledged as an important discipline, the full value of quality produce may not be realised. It is critical that farming businesses become more consumer led and deliver the requirements of the developing market. This is further emphasised by the fact that with trade barriers removed and logistics improved there is increasing competition, pushing prices down. Those farmers that invest in the food chain beyond the farm gate will be best placed to gain some share of the added value generated between the farm gate and the consumer. Indeed in a recent report by Agra Europe (Agra Europe, 2003) in 2002, UK agriculture added £7.12 billion to the UK economy which equates to just 0.8% of Britain's total economic gross added value. However, the amount of value that is added to food and drink once it leaves the farm gate is vast. Total household consumption on food and bought drinks in the UK at current prices, is £141 billion. This means that £80 billion was added in value to food once it leaves the farmers hands, a twelvefold increase.

The development of the LEAF Marque has offered the opportunity of reconnecting for farmers. The LEAF Marque is about 'Linking Environment And Farming'. It gives consumers the choice to buy affordable food produced by farmers who are committed to improving the environment for the benefit of wildlife and the countryside. Supported by 3 of the major UK retailers: Waitrose, Marks and Spencer and Safeways, the LEAF Marque fits in well with the food safety demands of the foundation assurance schemes. And encouragingly there is a good story to tell.

IFM delivers economic and environmental benefits (LEAF, 2003) and for the consumer there is a complete story for them to engage in, with full traceability on the web and a chance to see IFM in practice on a LEAF Demonstration Farm. Importantly LEAF Marque (LEAF Marque, 2003) has been developed in consultation with a wide range of stakeholder groups, farmers, consumers, environmentalists, animal welfare specialists and others in the industry. It is managed in collaboration with other schemes with accredited, independent external verification. This provides a good way for farmers to get recognised not only for good food production but also for farming well with care for their staff, animals and the environment – across the whole farm.

ENVIRONMENT

The countryside and the environment are no longer just a lifestyle perk of farming today the environment has become a potential source of revenue as funding is switched away from production. Perhaps more importantly, policymakers at all levels have more clearly identified that they can pay for these public goods, rather than paying more for the food production. Just two years ago, the income generated by environment or schemes was just one pound per hectare on average. In 2001/2002 this increased to six pounds per hectare (Agra Europe, 2003). Environmental schemes are seen as a way of improving public perception, as well as securing income. However, it must be acknowledged this will potentially reduce the farmers core business of food production.

Putting monetary value on landscapes is perhaps one of the greatest challenges. Agri-environment schemes have been set up to develop environmental good and account for compensation for some lost revenue, but the true economic reward for long term environmental delivery is still hard to define (Frame, 2002). Potentially through the LEAF Marque and the increased adoption of IFM does mean that consumers and farmers will benefit with closer connection to each other, with consumers starting to recognise their buying power.

And so to costing the part that agriculture plays in the environment. The pricing of environmental impacts is difficult to calculate as much of the value is taken for granted. The negative impact is perhaps quantifiable, and the Environment Agency has arrived at an environmental damage figure of £1.2 billion per year (Agra Europe, 2003). It is the positive impact that is also important. There are however positive environmental benefits deriving from agriculture which are harder to account for. Hartridge & Pearce, (2001) quantified the value of various features by the willingness of the public to pay for them, with the value of UK agriculture's environment services being put at just under £600 million.

It is evident that we need to more clearly define what we want out of the environment, Government set targets for the number of farmland birds to reach the levels of 30 years ago, these targets were achieved at Loddington in just 3 years. This 10 year study (Stoate & Leake, 2002) has taken place at Loddington in Leicestershire with the chief aim of sustaining an economically viable farm business, provide adequate pheasants for shooting and revive and conserve the wildlife on the farm. These objectives show a sharp contrast to farming post the introduction of the CAP when food was to be produced at any cost, namely the reduction of wildlife habitats. The Game Conservancy saw the opportunity to capitalise on using subsidy on set-aside to create habitat diversity without the farmer suffering financially.

Similar results were experienced from the Buzz Project (Farmed Environment Company, 2002), which set out to demonstrate the active management of arable cropping alongside environmental management within a profitable farming system. For example, they illustrated that when you clearly define what your targets are you can in effect "Dial a Habitat", through recognising the best options for the different flora and fauna that should be naturally there.

RECONNECTION

Finally the communicator, the term covers a very important part of the farming scene today. It includes the farmer who goes to drink in his local pub and talks to non-farmers about the industry building awareness of the real agricultural industry right through to the regular public speaker and those who welcome schools and other visiting parties to the farms. Everybody can and should do their bit or if not, there is little mileage in complaining about the press. The benefit obtained from educating the general public cannot be measured. LEAF has carried out extensive feedback from visitors, both farmers and non-farmers to its LEAF Demonstration Farmers and over 89% confirmed that their views and understanding of modern farming practices had changed as a result of visiting the farms. We have further spread our message by encouraging more and more farmers to 'Speak Out' about farming, with the production of an interactive communication tool designed for farmers to improve the PR of the industry. It is an escalating scale that with more knowledge hopefully comes better awareness and understanding of farming. From the Deloitte and Touche survey one respondent commented that it is the farmers responsibility to communicate to the general public, what we do and why we do it. We create our own success by believing in ourselves, and part of that is how we communicate with outsiders. We have some good opportunities ahead. It is critical. We all remain upbeat and ready to face the challenges.

The importance of communication, biodiversity and sustainability is further emphasised by Unilever (Langrange, 2002) who have adapted its agricultural activities to develop an appropriate policy on biodiversity. In particular how Unilever can use biodiversity to create value for its customers and itself. As IFM and sustainable agriculture are further developed management needs more insight into biodiversity social concerns and applications.

The combination of targeted technology and human capital inputs to produce high yield and nutritional quality keeping resource inputs as low as possible is critical. This approach minimises the adverse effects of farming on air, soil, water and biodiversity as has been demonstrated by the IFM research. Unilever sees agricultural biodiversity "as a challenge for making integration a reality". This means better communication between all parts of the agricultural sector and relevant institutions.

Consumers need to make an informed choice to buy the food they want to buy. They need to reconnect consumers with their food and understand how it is produced. Unilever's view of sustainable agriculture is seen as a combination of sound economics, environmental protection and social progress. Future labelling developments will be very important providing the customer with the link they need to the food they are eating, and communicating the story behind of how the food is produced. This is key to maintain links with the consumer in terms of how biodiversity is core to the enhancement of environmental concerns. Education must play an important role.

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A risk assessment framework for determining the effects of pesticides on farmland biodiversity

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ABSTRACT

A risk assessment to determine potential effects of pesticides on wider biodiversity, including direct effects on taxa not currently covered and indirect effects on others, is currently being developed. This paper describes the framework within which the development is taking place, and the approaches which are being used. The framework includes consideration of which taxa should be conserved, the risk assessment approach, when a wider biodiversity risk assessment is needed and what risk management and/or mitigation practices might be employed to offset any risks which are identified. Two quantitative case studies will be produced to exemplify the risk assessment process.

INTRODUCTION

Wildlife co-exists with agriculture both within and outside the cropped area. Pesticides applied to crops may adversely affect this wildlife, therefore prior to the authorisation of any pesticide a risk assessment is carried out. This risk assessment currently covers the risk to the following non-target organisms: birds, mammals, aquatic life, non-target arthropods, honeybees, soil microbial processes, soil macroinvertebrates (including earthworms) and non-target plants. Only when the risk to each of these areas is considered acceptable is authorisation granted. (Further details regarding the current ecotoxicology regulatory risk assessment can be found at http://www.pesticides.gov.uk/applicant/registration_guides/data_reqs_handbook/ecotox.pdf.)

The above process is primarily focussed on the direct effects of pesticides on non-target organisms, i.e. the toxicity of the pesticide to the non-target is compared to the potential exposure and an assessment made as to whether there will be adverse effects. There is the potential for the population to recover is considered, there is no consideration of whether the decline in non-target arthropods due to the effects of a pesticide may be adversely affecting other wildlife, e.g. birds. Therefore, as it is stated in the recent paper from the Department for Environment, Food and Rural Affairs (Anon. 2002) that 'the management of farming and agricultural land so as to conserve and enhance biodiversity as part of the Government's Sustainable Food and Farming Strategy' should be encouraged, a proposed risk assessment to determine potential effects on wider biodiversity is being developed.

RELEVANT TAXA

The first step in developing the risk assessment was to determine which taxa should be considered. At present, the risk assessment encompasses arable and horticultural farmland and associated off-crop habitats. Three categories were identified:

(a) UK biodiversity indicator species (Biodiversity Action Plan (BAP) species www.ukbap.org.uk) relevant to agricultural and horticultural environments as well as those covered by the relevant farmland Habitat Action Plans.
(b) Other species that are particularly important in ecological processes (e.g. food chains to birds and mammals and key species in the decomposition process).
(c) Other significant species not covered by (a) and (b), e.g. rare or declining species.

In-field and off-field taxa are considered separately. It is recognised that some rare and BAP species have very restricted distributions, and may be better conserved through other means. Therefore, the chosen lists are used to represent the major life histories and phenologies present in the agricultural environment which the risk assessment needs to address.

It is important to understand the context in which the risk assessment is being developed. It does not aim to provide complete protection to all species on the lists, for two reasons:

(i) Some species, particularly in category (b) above, are relatively common, and may have damaging effects on crop productivity if present in significant quantities, e.g. the weed species *Chenopodium album* and *Stellaria media*, which are included because of their importance as sources of food for declining bird species. Clearly, total protection of these species is not realistic. Similar comments could apply to some invertebrate species.
(ii) Measures arising from the risk assessment should be proportionate and not place undue burdens on agriculture and the agrochemical industries.

The aim is therefore to manage farmland in a way which conserves populations of species or those dependent on them at an acceptable level, without unacceptable impacts on crop production. Approaches to risk management and/or mitigation are therefore crucial. These are considered in more detail later.

THE RISK ASSESSMENT APPROACH

The remit covers a potentially large number of species and ecological interactions. It is not feasible to address all of these individually, so a generic approach has been adopted, illustrated by case studies.

Protection goals and measures of risk

Protection goals have been set as follows. For species in category (a) above, the use of pesticides should not have any adverse effect on the achievement of, or progress towards, BAP targets for species of concern, either locally or nationally. For those covered by category (b), any impact on these species should not result in adverse effects on relevant species in categories (a) and (c). For species in category (c), the use of pesticides should not contribute further to their decline, either directly or indirectly, nationally or locally.

Appropriate measures of risk need to be identified to quantify the potential impact of pesticide effects on the protection goals. These need to be practical to assess and interpretable for risk managers. Examples might be the probability of achieving a BAP target, or the probability that the population growth rate is greater than 1 (i.e. the population is increasing).

Which species should be used in tests?

This question is being addressed primarily for plants, as other projects are investigating species selection for arthropods. For off-crop situations, the appropriateness of the ESCORT II approach for arthropods (Candolfi *et al.*, 2001)) will be assessed.

A range of plant species needs to be selected which represents the range of susceptibilities to the pesticide being tested. As far as possible, species already commonly tested will be included, though some additional species may also need to be added. Datasets covering a range of species and active ingredients, provided by Rothamsted Research and the Canadian Wildlife Service, are being used to answer the following questions:

1. Can appropriate indicator species be identified from information already available for the species to be protected?
2. If not, what further work is required to identify suitable indicators?
3. Can crop species be used as indicators?
4. If not, are suitable non-crop species available (i.e. in terms of seed availability, consistency, germination rate, ease of cultivation)?
5. How can uncertainty concerning toxicity (especially regarding extrapolation between species) be quantified?

As far as possible, the risk assessment is being developed using data currently submitted under European Union (EU) regulation 91/414/EEC. Where data requirements extend beyond those required under 91/414/EEC, this will be identified.

Which test endpoints should be used?

The appropriateness of commonly used test endpoints as predictors of potential impacts on plant populations needs to be assessed, and any requirement for additional endpoints for plants with contrasting life-history strategies considered. It may be possible to predict one endpoint from another (e.g. seed production from biomass).

Extrapolation

Extrapolation is required to predict risk from test results. This may be done using subjective factors based on expert judgement or quantitative factors based on uncertainty analysis.

Species sensitivity analyses will be developed as a basis for proposing uncertainty factors for extrapolation between species. Uncertainty analyses will also help to identify areas of greatest uncertainty, which would be priorities for future research.

Exposure

The approach to estimating exposure is based on current regulatory practice. For in-crop assessment, full field application rates are assumed, adjusted if appropriate for interception by the crop. The approach to off-crop exposure uses the methods of estimating spray drift developed by Ganzelmeier, as amended by Rautmann *et al.* (2001).

Higher trophic level assessment

This requires knowledge of relationships between direct effects on plants and/or invertebrates and indirect consequences at higher trophic levels. The report of a recent study on "Modelling the effects on farmland food webs of herbicide and insecticide management in the agricultural ecosystem" (Sutherland, 2002) will inform the development of the risk assessment, in conjunction with results from a current project on "Assessing the indirect effects of pesticides on birds" (Boatman *et al.*, in press). A stepwise assessment procedure is being developed, incorporating uncertainty factors defined on the basis of expert judgement combined with probabilistic modelling.

WHEN TO CARRY OUT A WIDER BIODIVERSITY RISK ASSESSMENT

It may be that a wider biodiversity risk assessment is not needed for some crops, for example (i) because they cover a very small area, or (ii) because they are not important for biodiversity, or (iii) because the pesticide is applied at a time of year when the impacts will be negligible.

(i) Area covered. The proportional area occupied by different crops has been determined at national, regional and local scales from Defra agricultural statistics. In some cases, a crop covering a small proportion of farmed land nationally may have local significance which warrants a risk assessment at that level.

(ii) Value for biodiversity. Crops vary in their value for biodiversity, and a review of published and available unpublished literature is in progress, to summarize existing information and identify knowledge gaps. The need for risk assessments will clearly be greater for crops with a high potential biodiversity value.

(iii) Timing. Phenology of organisms under consideration can be used as a basis for assessing potential impacts of pesticide use in relation to approved application timings. Empirical information, where available, can be used to support such assessments (e.g. Ewald & Aebischer, 1999).

The risk assessment procedure can be run for different crops under a worst case pesticide impact scenario based on information from (i) – (iii) above. Where this worst-case impact is judged to be acceptable, further risk assessments would not be required.

RISK MANAGEMENT AND MITIGATION

Where a significant risk is identified, risk management measures need to be implemented. Two categories have been identified, mitigation and compensation measures. Mitigation measures are those which directly reduce or eliminate a risk. Such measures could include, for example, alterations in dose rate or timing, or the use of buffer zones. Compensation measures provide an alternative resource to compensate for that lost as a result of pesticide use. Examples could include wild bird seeds mixtures or pollen and nectar mixtures, perhaps managed as part of an agri-environment scheme. Some measures, e.g. conservation headlands, could perform both mitigation and compensatory functions. Quantitative links between pesticide impacts and effects of mitigation or compensatory measures need to be developed.

A requirement for appropriate risk management approaches could be implemented, as part of the pesticide registration process, where the risks identified apply to widely occurring organisms (e.g. some BAP bird species). However, for rare species which are restricted in their distribution, risk management would be more appropriately applied at a local level, e.g. through agri-environment schemes.

CASE STUDIES

To illustrate the application of the risk assessment framework, two case studies are under development.

Case study 1. Broad spectrum insecticide

This case study focuses primarily on the indirect effects of a summer applied broad spectrum insecticide on birds. Two species are being used to model pesticide impacts: grey partridge (a nidifugous[1] species which feeds in cereal crops) and yellowhammer (a nidicolous[2] species feeding in a range of crops and field margins). Data for the latter species are available from a parallel study on "Assessing the indirect effects of pesticides on birds" (Boatman *et al.*, in press; Morris *et al.*, 2002)

Case study 2. Broad spectrum herbicide

The second case study addresses issues arising from herbicide effects on non-target plants within the crop, particularly in terms of the indirect effects on invertebrates or vertebrates. It does not include impacts on rare or BAP plants, because in most cases it will be more appropriate to manage risk at a local scale (see risk management and mitigation above). Models of impacts on seed production and effects on seed-eating species are available (Watkinson *et al.*, 2000; Sutherland, 2002), though further development is needed. Modelling of indirect effects on insectivorous species is currently only possible at an empirical level (Sutherland, 2002), as relationships between plants and invertebrates in arable crops are poorly understood, and there is a need for further research in this area. Limited data are available to support such empirical models, which can be used as a basis for risk assessment in some areas until further data become available.

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[1] Young leave the nest soon after hatching

[2] Young remain in the nest

DISCUSSION

The research described here will develop a scheme for assessing pesticide risks to wider biodiversity. This will be monitored by the Advisory Committee on Pesticides (ACP) Environmental Panel Subgroup on Wider Biodiversity, which produced the underlying framework for the scheme, and after approval by the subgroup and the ACP, will be submitted for consultation to other stakeholders in spring 2004. The aim throughout is to develop a workable scheme to conserve biodiversity on farmland, without placing unacceptable burdens on farmers or the agrochemical industry. In the process of developing the scheme, knowledge gaps will be identified and further research needs identified in order to provide the necessary data to carry out risk assessments under the scheme. Consideration will also be given to further issues not covered by the present scheme, which may need to be incorporated in to future risk assessments.

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