AN INSIGHT INTO THE IMPACT OF ARABLE FARMING ON IRISH BIODIVERSITY: A SCARCITY OF STUDIES HINDERS A RIGOROUS ASSESSMENT

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ABSTRACT

To help understand and counteract future agronomic challenges to farmland biodiversity, it is essential to know how present farming practices have affected biodiversity on Irish farms. We present an overview of existing research data and conclusions, describing the impact of crop cultivation on biodiversity on Irish arable farms. An extensive literature review clearly indicates that peer-reviewed publications on research conducted in Ireland on this topic are quite scarce: just 21 papers investigating the effect of conventional crop cultivation on Irish biodiversity have been published within the past 30 years. Principally, these studies have concluded that conventional crop cultivation has had an adverse impact on biodiversity on Irish farms, with 15 of the 21 studies demonstrating negative trends for the taxa investigated. Compared to other EU states, the relative dearth of baseline data and absence of monitoring programmes designed to assess the specific impacts of crop cultivation on Irish biodiversity highlight the need to develop long-term research studies. With many new challenges facing Irish agriculture, a research programme must be initiated to measure current levels of biodiversity on arable land and to assess the main farming 'pressures' causing significant biodiversity loss or gains in these systems.

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INTRODUCTION

Although agriculture led to the development of human civilisation and is required for the continuity of human society, it has also been identified as one of the principal contributors to the loss of biodiversity worldwide, largely because of the vast terrestrial areas of the planet devoted to farming (McLaughlin and Mineau 1995; Goklany 1998). The high degree of physical manipulation (ploughing, irrigation, etc.) and high inputs of pesticides and fertilisers inherent in many farming models also impact on biodiversity (McLaughlin and Mineau 1995). While the 'green revolution' of the 20th century significantly increased their extent and intensity, these impacts have nonetheless been a feature of agriculture since the very beginning (Diamond 2005). The timeline of agricultural development in Ireland has seen the loss of primary broadleaf-forest cover on the island, reductions of floral diversity in natural grasslands and losses of animals such as wolves and eagles, and the drainage of bogs and marshes has led to the loss of bird species such as the bittern (*Botaurus stellaris*) (Mitchell and Ryan 1997; Feehan 2003). Conversely, successive waves of agricultural development have been responsible for many species introductions to Ireland, whether as introduced domesticated or edible species, such as rabbit (*Oryctolagus cuniculus*), or as weedy species, such as wild oats (*Avena fatua*) and the darnel (*Lolium temulentum*) (Reynolds 2002; Stokes *et al.* 2004).

Tillage and land-use systems in Ireland continue to change (e.g. the modern declines in flax and sugar-beet cultivation or increases in maize and oilseed-rape cultivation), and new floral and faunal elements appear from overseas all the time, so current arable farmland biodiversity should be properly interpreted as part of a longer-term flux where change is the norm. Therefore, baseline data regarding biodiversity change will have to be anchored towards specific tillage systems and will have to define the timescales of biodiversity change that are of relevance. Equally, these measurements require analysis of both numbers of species and also the density and diversity of individuals and populations within species.

Perhaps the most striking knowledge gap evident from the literature is that the direct contribution of tillage-based agriculture to species decline, as opposed to decline caused by other land uses (e.g. grassland, etc.), has not been quantified for Ireland. Arable land receives heavier applications of pesticides (Meade and Mullins 2005) and is cultivated more frequently (annually) than

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grassland (approximately 53% of pastures in Ireland have not been cultivated for reseeding in more than ten years; O'Brien *et al.* 2008), so there is greater pressure on the various species present. While environmental pressures faced here may differ from other European countries (see below), many EU studies suggest that major recent declines in biodiversity are associated with agricultural change, particularly since the 1950s, and we might expect a similar trend to be evident here (Donald *et al.* 2001; Robinson and Sutherland 2002). These apparent changes have been a major driver for legally binding conservation policy at an EU level.

Ireland (primarily referring to the Republic of Ireland from this point on, unless stated otherwise) is unique in Europe in that agriculture is overwhelmingly grassland oriented, with a predominance of small fields: just 10% of farmland is arable (some 0.42 million ha), mostly comprised of cereals (0.31 million ha), with the remaining 90% (3.8 million ha) devoted to pasture, meadow and silage (European Environment Agency 2005; Department of Agriculture and Food 2006a). Within the arable farmland it is evident that recent changes have significantly impacted on habitat quality; for example, arterial and field drainage, land reclamation (including the removal of small-scale farmland habitats such as trees, hedges, drystone walls, remnant woodlands and scrub) and the increasing use of fertilisers and pesticides (insecticides, fungicides and herbicides) (Feehan 2003).

External inputs, such as pesticides and fertilisers, are a major feature of crop production in Ireland. Total pesticide inputs for arable crops in 2004 (based on active substances) amounted to 1,520 tonnes, including 663 tonnes of herbicide, 619 tonnes of fungicide, 29 tonnes of insecticide and 209 tonnes of other plant-protection products (e.g. growth regulators, molluscicides, etc.) (Department of Agriculture and Food 2007). Overall, there has been an 18.4% increase in pesticide usage (based on sales) since 1990 (Organisation for Economic Cooperation and Development (OECD) 2004), although the average amount of pesticide used in 2001 was 0.5kg active ingredient per ha of Irish agricultural land, which was the lowest in the EU-15. However, the low level of pesticide usage in Ireland would seem to reflect the relatively small proportion of land dedicated to arable farming compared to other EU countries and the lower quantity of pesticide usage on grassland farms (Department of Agriculture and Food 2006b).

As farming has intensified, the use of artificial (inorganic) N fertiliser has also increased, both to increase yields and to improve nutritional status (Smil 2002). However, only a fraction of the N applied is used in plant growth or retained in food products; the excess leads to biodiversity loss and reduced water quality (Hassan *et al.* 2005). The quantities used on Irish farms increased from 48,000 tonnes in 1966–7 to 275,000 tonnes in 1980 (Murphy 1982) and continued to increase from 370,000 tonnes in 1990 up to 444,000 tonnes in 1998 (OECD 2004). As the cost of fertiliser N has increased in recent years, and the EU Water Framework Directive has come into force in Ireland, there has been some reduction in usage. In 2003 388,000 tonnes of N and 44,000 tonnes of P were used on Irish farms, with land for arable crops receiving a higher unit application of each nutrient (Coulter *et al.* 2005). Nitrogen usage for cereals increased by approximately 11% from 1995 to 2003, but P use remained constant. In the same period the usage of N and P for root crops (e.g. turnip, potato, sugar beet and fodder beet) decreased markedly by 14% and 24%, respectively (Coulter *et al.* 2005). As of 2001, Ireland applies 130kg of NPK fertiliser per ha of farmed land compared to the OECD average of 123kg ha^{-1}. This rate is the sixth highest of the EU-15, with the Netherlands (210kg ha^{-1}) being the highest and Greece (49kg ha^{-1}) being the lowest (OECD 2004).

This paper aims to provide an insight into existing research data and conclusions from peer-reviewed publications regarding the impact of crop cultivation on biodiversity on Irish tillage farms. Although there is an abundance of literature on this topic collated from other regions in Europe and elsewhere (e.g. McLaughlin and Mineau 1995 (Canada); Robinson and Sutherland 2002 (Great Britain)), such a record does not exist for Ireland. In addition to the varied climate and different agronomic systems in Ireland, we cannot rely too heavily on *ex situ* studies because, in comparison with Great Britain and continental Europe, the terrestrial fauna and flora of Ireland is relatively impoverished, reflecting Ireland's isolation by sea since the last glaciation (Costello 1993; Mitchell and Ryan 1997). Given the relative lack of Irish research on this issue in general, the purpose of this review is to ascertain through published, peer-reviewed scientific literature exactly what is known about the positive and negative impacts of conventional crop cultivation on inter- and intra-species biodiversity on farms on the island of Ireland. The literature review is primarily limited to comparative/experimental studies that target specific arable cropping systems, rather than baseline data available in databases or in local natural-history or biogeographical journals.

IMPACT OF CONVENTIONAL CROP CULTIVATION ON BIODIVERSITY ON IRISH TILLAGE FARMS

Reduced levels of biodiversity are associated with increased intensity of management and reduced environmental heterogeneity (Erwin 1996). A number of species and species assemblages in Ireland are dependent upon the continuation of specific agricultural practices for their survival (see below). However, changes in and intensification of modern agricultural practice, such as the switch from spring to winter crops, the loss of marginal hedgerows and the decline in the area under cultivation, have over the past three decades caused a dramatic decrease in many species that are dependent on traditional arable practices, such as bristle oat (*Avena strigosa*) and darnel (*Lolium temulentum*) (Curtis *et al.* 1988; The Heritage Council 1999; Taylor and O'Halloran 2002). Similarly, the loss of overwintering stubble and the abandonment of small-scale rotational cropping have had an adverse impact on biodiversity (The Heritage Council 1999; Taylor and O'Halloran 2002; McMahon *et al.* 2003). Marginal hedgerows and wet flush areas are a characteristic feature of the Irish farming landscape and form important wildlife habitats for animals and plants (Mitchell and Ryan 1997; Feehan 2003). Webb (1988) estimated that approximately 16% of all hedges have disappeared since 1938, and the total area drained under various Acts and Schemes is 2.02 million ha, or almost 38% of the total land area farmed on the island of Ireland. Although the focus in this current paper is on arable systems, it is possible that the impacts of such changes are also likely to be as great on the biodiversity of pastoral systems (Green and Stowe 1993; Hutton and Giller 2003; Purvis *et al.* 2005).

Research on the effects of agricultural practices on Irish levels of biodiversity was collated from a literature search, using ISI Web of Science (1945–2006), BIOSIS Previews (1980–2006) and CAB Direct (1973–2006). There have also been a number of relevant MSc and PhD theses in Ireland completed on this topic in the last decade (e.g. Fadl 1996; Davis 2004; Bracken 2004; McMahon 2005; Golden 2005; Brennan 2005). However, only peer-reviewed articles stemming from those theses have been included here, with the caveat that some of the studies are of a higher scientific standard and are published in higher-impact journals than others.

Considering the importance of agriculture to the Irish economy and the increasing national interest in biodiversity, it is of some concern that only 21 published, peer-reviewed scientific articles have investigated the impact of crop cultivation on farmland biodiversity in Ireland over the last three decades (twenty studies in the Republic of Ireland and one study in Northern Ireland; Table 1). Three of these studies were published in the 1980s, and three in the 1990s. However, since 2000, the rate of publication has increased, with fifteen scientific papers published in the last seven years. The majority of this research has focused on improving soil-management practices (i.e. crop rotation/effects of cultivation and intercropping, 9 of 21 studies), the benefits of maintaining hedgerows/forests crossing or bordering tillage fields (3/21) and the adverse effects of intensification (3/21) (Fig. 1). Other research areas studied included pesticide usage, set-aside and stubble, organic farming and the Rural Environment Protection Scheme (REPS). Fifteen studies assessed the effects of cropping using biodiversity 'indicator' species such as various invertebrate groups (of agronomic importance), with one of these studies also examining vascular plants; five others focused on birds (that were either very rare or very common); and one focused on mammals (bats). The most-studied invertebrates in these papers were earthworms, carabid beetles and collembola (springtails). Bats and bumblebees were the only mammals (Russ and Montgomery 2002) and airborne insects (Santorum and Breen 2005) studied as biodiversity indicator species, respectively. The choice of species to be used as indicators of biodiversity change remains a somewhat contested question, in addition to the ecological questions that such indicator species can answer. As in many countries and ecosystems, biodiversity-change studies in Ireland have mainly taken a community-ecology approach, often on a few groups of organisms, including invertebrates, songbirds and small mammals (Pereira and Cooper 2006; Thompson 2006). Based on the conclusions of the literature reviewed for this review, the impact of arable farming practices on these various organisms has been summarised as follows:

SOIL MANAGEMENT PRACTICES

Earthworms are one of the most important groups of beneficial soil invertebrates in cropping systems in north-western Europe, contributing to soil fertility and productivity (Lee 1985). Carabid beetles in agricultural crop systems have a beneficial role as polyphagous predators of pest species (Thiele 1977; Luff 1987), and springtails can be microphages, feeding on soil microflora, and/or detritivores, scavenging on dead organic matter and plant litter (Bardgett *et al.* 1993). Under Irish conditions, conventional soil cultivation (i.e. mechanical ploughing, tilling, etc.) has been found to have an adverse effect on the species diversity of soil organisms, such as earthworms (Schmidt and Curry 2001; Schmidt *et al.* 2001; Curry *et al.* 2002), carabid beetles (Fadl *et al.* 1996; Purvis *et al.*

Table 1—Pre-existing peer-reviewed research data describing the impact of conventional crop cultivation on Irish levels of biodiversity (1980–2006).

Investigated species/group	*Crop(s)*	*Study*	*Statistical analysis*	*Study duration*	*Results*	*Impact on biodiversity*[1]	*Reference*
Arthropod fauna	Barley & grass–white clover	Successional changes in arthropod fauna of a newly established ley pasture that was previously cultivated arable land	Yes	1975–7	Soil and foliage communities increased in species richness after grassland was established on arable land.	↓	Purvis and Curry (1980)
Carabid beetles	Sugar beet	Comparison of manure application at the time of sowing and unrestricted weed growth with controls	Yes	1979	Manure application immediately encouraged early-season carabid communities.	↓	Purvis and Curry (1984)
Arthropod fauna	Winter wheat	Effects of various methods of methiocarb application on non-target invertebrates	Yes	1980–1	Single applications of methiocarb granules did not adversely affect the predatory and decomposer fauna.	↔	Kelly and Curry (1985)
Staphylinid beetles	Spring cereals, winter cereals, hay meadow, lightly grazed pastures & silage fields	Effects of different cereal- and grass-management regimes on summer staphylinid assemblages	Yes	1986	Large differences in staphylinid assemblages occurred between undisturbed meadows and pastures and disturbed silage fields and cereals.	↓	Good and Giller (1991)
Carabid beetles	Winter wheat	Effect of repeated annual application of methiocarb-based slug pellets on carabid beetle activity	Yes	1987–91	Even though methiocarb application can severely depress winter-active carabid populations, the long-term environmental harm of this non-target effect appears to be relatively slight.	↔	Purvis and Bannon (1992)
Pterostichus melanarius (beetle)	Mixed tillage	Comparison of four different timed cultivation histories	Yes	1992–4	Spring soil cultivation reduces larval/pupal survival, but rapid inter-field dispersal by adults masks the effects of soil cultivation on individual fields.	↔	Fadl *et al.* (1996)
Carabid beetles	Mixed tillage & grassland	Effect of different timings of annual soil cultivation on numbers and types of beetles	Yes	1992–4	In a mixed farming system, a greater degree of species coexistence and biodiversity is possible compared to monoculture farming with synchronised soil cultivation.	↓	Purvis *et al.* (2001)

Table 1 (*Continued*)

Investigated species/group	*Crop(s)*	*Study*	*Statistical analysis*	*Study duration*	*Results*	*Impact on biodiversity*[1]	*Reference*
Earthworms	Winter wheat & winter wheat–white clover	Effect of winter wheat–white clover intercropping system (low input, direct drill) compared to conventional monocropping	No	1994–6	The combination of absence of tillage and continuous supply of plant residues of high nutritional value in the wheat–clover intercropping system was beneficial to earthworms.	↓	Schmidt and Curry (2001)
Earthworms	Winter wheat & winter wheat–white clover mix	Effect of low-input, direct-drill intercropping system compared to conventional monocropping	Yes	1993–7	The results show unequivocally that the wheat–clover cropping system supported larger earthworm communities than conventional wheat monocropping.	↓	Schmidt *et al.* (2001)
Earthworms	Wheat, potato & spring barley	Impact of intensive cultivation	No	1994–2000	Earthworm populations can be virtually eliminated within a single season by drastic forms of soil cultivation.	↓	Curry *et al.* (2002)
Carabid beetles	Potato	Compare carabid beetle communities in organic and conventional potato crops	No	1999	Greater abundance and diversity of carabid beetles were found in the organic plots.	↓	O'Sullivan and Gormally (2002)
Carabid beetles	Mixed tillage & uncultivated grass leys	Compare crop-rotation and soil-cultivation effects on beetles	Yes	1993–5	Autumn-breeding carabid species were less common in early summer when soil cultivation was carried out in late spring compared with uncultivated or autumn-sown fields.	↓	Purvis and Fadl (2002)
Bats	28 habitat types	Species richness in the Northern Ireland countryside	No	1996–8	Reduction in areas and quality of habitats such as field boundaries may impact on bat populations.	↓	Russ and Montgomery (2002)[2]
Corn bunting	Cereals & other tillage crops	Survey of potential corn bunting habitats in counties Donegal, Mayo and Galway	No	1998	No corn buntings were seen or heard at any of these sites.	↓	Taylor and O'Halloran (2002)
Birds	Stubble, set-aside, grassland & winter wheat	Species richness in farmland	Yes	2001–2	Stubble supports the greatest species richness and diversity, with the lowest being recorded on improved grassland.	↑	McMahon *et al.* (2003)

Table 1 (*Continued*)

Investigated species/group	*Crop(s)*	*Study*	*Statistical analysis*	*Study duration*	*Results*	*Impact on biodiversity*[1]	*Reference*
Plant flora and carabid beetles	Mixed tillage	Species richness in field boundaries with and without REPS	Yes	2000	Species richness of plants and carabid beetles was similar on REPS and non-REPS tillage farms.	↔	Feehan *et al.* (2005)
Birds	Mix of tillage, forest & grassland	Species richness and abundance in three landscape units of either intermediate or low-level forest cover	Yes	2001–2	Although farmland bird species richness and abundance between partially forested and open sites did not differ, the presence of trees in the surrounding landscape did positively influence the abundance of blue tits, robins and blackbirds.	↑	Pithon *et al.* (2005)
Bumblebee	Mixed tillage & grassland	Bumblebee diversity and abundance on farmland	No	2003–4	The findings suggest an impoverishment of bumblebee species diversity on Irish farmland.	↓	Santorum and Breen (2005)
Birds	Mixed tillage & grassland	Investigate whether farmland bird species showed preferences for set-aside over tillage and grassland fields	Yes	2003	Species diversity and richness were greater in the eighteen set-aside sites compared with their paired grass and tillage sites.	↓	Bracken and Bolger (2006)
Collembola	Winter wheat	Compare collembola assemblages in plots ploughed in a conventional way with plots subjected to conservation tillage	Yes	2003	The number of collembola in conservation-tilled plots was significantly higher than in the conventionally tilled plots, but there was little effect on species richness.	↓	Brennan *et al.* (2006)
Robin	Spring barley	Role of habitat and structural hedgerow components in determining breeding densities of robins	Yes	1999	There were significantly fewer robin territories per ha in arable sites due to lower hedge density.	↓	Fennessy and Kelly (2006)

[1]Impact of conventional crop cultivation on biodiversity either (i) prior to the land being used for other purposes (e.g. meadow, pastures), (ii) compared to alternative environment-friendly farming practices, such as intercropping, minimum tillage, timing of cultivation, organic farming, set-aside, winter stubble and farming under REPS, or (iii) resulting from the general intensification of farming practices.
[2]Northern Ireland.

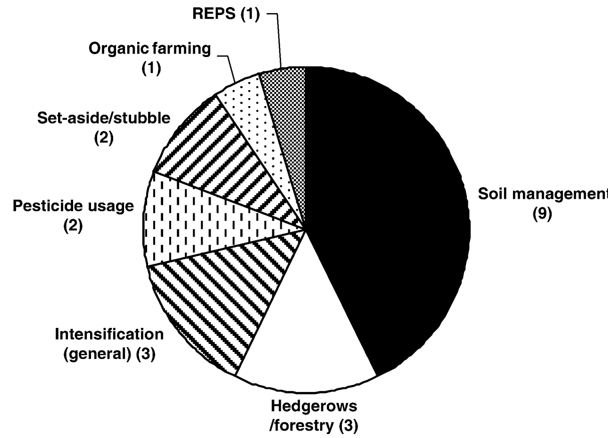

Fig. 1—Arable farming operations and practices that have been shown as having either a positive or negative impact on Irish levels of farmland biodiversity (n = 21 published studies). Data collated from peer-reviewed publications using ISI Web of Science (1945–2006), BIOSIS Previews (1980–2006) and CAB Direct (1973–2006).

2001; Purvis and Fadl 2002), collembola (Brennan *et al.* 2006) and other arthropods (Purvis and Curry 1980). In contrast, minimum tillage (Brennan *et al.* 2006), minimum tillage with intercropping (Schmidt *et al.* 2001; Schmidt and Curry 2001), reversion of land from tillage to grassland (Purvis and Curry 1980) and timing of cultivation (Fadl *et al.* 1996; Purvis *et al.* 2001; Purvis and Fadl 2002) have all been shown to be less detrimental to populations of these organisms. Farmyard-manure application to soil at the time of sowing has also been shown to significantly encourage early-breeding carabid communities (Purvis and Curry 1984). The use of manure replenishes N and other elements in the soil and builds up soil organic-matter content. This generally supports a greater abundance of invertebrates that rely on non-degraded plant matter as a food source (Hole *et al.* 2005).

HEDGEROWS AND FORESTRY

Up to 1.5% of the total land area of Ireland is accounted for by hedgerows (Webb 1988). Hedgerows accommodate a greater total of breeding birds than any other farmland feature by providing movement corridors; protection from predators; and nesting, feeding and roosting sites (O'Connor and Shrubb 1986; Lack 1992). The presence of hedgerows and forests in and around tillage farms has had a positive effect on populations of bats and certain birds, such as the blue tit (*Parus caeruleus*), robin (*Erithacus rubecula*) and blackbird (*Turdus merula*) (Russ and Montgomery 2002; Pithon *et al.* 2005; Fennessy and Kelly 2006). The loss of hedgerows represents a direct loss of foraging habitat for several bat species (Russ and Montgomery 2002) and of feeding, nesting and roosting sites for bird species such as the robin (Fennessy and Kelly 2006). Fennessy and Kelly (2006) found that arable sites had significantly fewer robin territories per ha than either improved or semi-improved grassland sites. This may be explained by the fact that hedge density was significantly lower in arable land than in the other two farmland groupings.

INTENSIFICATION OF FARMING

Agricultural intensification can be defined as the production of more agricultural goods with the same amount of resources, such as land and water. The intensification of Irish agriculture has been implicated in the impoverishment of bumblebee species diversity (Santorum and Breen 2005) and the decline and extirpation of the corn bunting (*Miliaria calandra*) from much of its range (Taylor and O'Halloran 2002). Bumblebees are an important part of the Irish fauna, particularly as pollinators of both wild plants and agricultural crops. Bumblebees that would be naturally rare are now very scarce or absent from the typical agricultural landscapes surveyed (Santorum and Breen 2005). With regards to the corn bunting, the most important factors in its demise in western European countries, including Ireland, are thought to be the decline in mixed farming and the loss of temporary grasslands, hay meadows and undersown cereals, especially spring cereals and overwintering cereal stubbles. These crops provided the preferred breeding and overwintering habitats, and the use of pesticides is proposed to have possibly reduced the availability of invertebrate and seed food supplies (Taylor and O'Halloran 2002).

Predatory staphylinid beetles comprise one of the groups of polyphagous natural enemies of pest insects in cereals and agricultural grasslands (Good and Giller 1988). Good and Giller (1991) examined the effects of different cereal- and grass-management regimes on summer staphylinid assemblages in hay meadows, lightly grazed pastures, silage fields, spring cereals and winter cereals with routine pesticide applications. Large differences in staphylinid assemblages occurred between undisturbed meadows and pastures (without cultivation, cutting, heavy grazing or fertiliser use) and disturbed silage fields and cereals. Application of dimethoate insecticide resulted in a reduction in species richness in cereals, but no effect was evident from the use of the fungicide propiconazole. Overall, rapid recolonisation in heterogeneous landscapes, as in this study, lessened the perceived impact of disturbance factors (Good and Giller 1991).

PESTICIDE USAGE

Two studies have analysed the impact of pesticide usage on Irish biodiversity (Kelly and Curry 1985; Purvis and Bannon 1992). A single application of methiocarb-based slug pellets was found not to adversely affect predatory and decomposer fauna (Kelly and Curry 1985), but repeated annual broadcast and drilled applications severely depressed the populations of winter-active carabid populations to less than 5% and 10–15%, respectively, compared with untreated plots (Purvis and Bannon 1992). However, the long-term environmental harm of applying methiocarb-based slug pellets on non-target organisms appeared to be relatively slight in those authors' opinion (Purvis and Bannon 1992). Although the effects of herbicides have only been tentatively studied on arable farms (Feehan *et al.* 2005), it is believed that their use over the past half-century has halved the number of wild plants and animal species associated with farmland and has greatly reduced the overall population size of most species (Feehan 2003).

WINTER STUBBLE AND SET-ASIDE

Winter stubble and spring-sown cereals have been relatively common features of the Irish landscape in recent centuries, up to the spread of winter sowing in the 1980s (Feehan 2003). Winter stubble comprises an important food source for many species of farmland birds over the winter months, and spring-sown cereal crops provide favourable nesting conditions for ground-nesting birds, such as skylarks (*Alauda arvensis*), which have suffered a decline of 25–50% in breeding populations over the last 25 years (Newton *et al.* 1999; Taylor and O'Halloran 2002; McMahon 2005). Set-aside was initially introduced in 1992 to reduce overproduction and agricultural surpluses in the EU (Buckingham *et al.* 1999). 'Green' set-aside has since emerged within the context of multifunctional agriculture in the EU to also become part of some agri-environment schemes (Sotherton 1998). Rotational set-aside helps to maintain more land under winter stubble, as farmers previously would plough their fields soon after harvest in readiness for sowing the following year's crops. On the other hand, non-rotational set-aside is land that is left fallow for several years and that may be sown either with grass or with naturally regenerated vegetation. McMahon *et al.* (2003) showed that arable farms that retained stubble throughout the winter supported the greatest diversity of birds. Bracken and Bolger (2006) found birds exhibited a significant preference for set-aside over non-set-aside fields (i.e. grass and tillage sites), with non-rotational set-aside having the greatest abundances of species, such as skylark and meadow pipit (*Anthus pratensis*).

RURAL ENVIRONMENT PROTECTION SCHEME

Following the implementation of Council Regulation (EEC) 2078/92, REPS was introduced to Ireland in 1994 (the Northern Ireland equivalent is the Environmental Sensitive Area scheme and/or Countryside Management Scheme). REPS is intended to monetarily reward farmers for carrying out their farming activities in an environmentally friendly manner and to bring about environmental improvement on existing farms. The fifth Common Agriculture Policy (CAP) reform established common conditions for direct payments to farmers under the various income-support schemes and provided support for the agri-environment. Since its launch in 1994, over 45,000 Irish farmers have joined REPS, with approximately 39% (or 1.7 million ha) of the utilisable agricultural area of Ireland being farmed under REPS guidelines.

One of the original stated objectives of REPS was 'to protect wildlife habitats and endangered species of flora and fauna' (Teagasc 2007), but throughout the scheme's specifications the main emphases have been extensification and water-pollution reduction (Feehan *et al.* 2005). However, investigating the plant flora and carabid beetle species richness in field boundaries on REPS and non-REPS tillage farms, Feehan *et al.* (2005) found species richness was actually similar on both. The authors concluded that farms that had participated in the scheme for at least four years, so far, showed little beneficial impact on the diversity of flora and surveyed fauna groups. As the study relied on data from short- and medium-term monitoring, the authors acknowledged that a longer-term study is required.

ORGANIC FARMING

At the end of 2006 there were approximately 72 organic arable farmers in Ireland, farming 620ha, which represented approximately 0.1% of the agricultural land area (Shortle *et al.* 2007).

Organic agriculture is based on a broad set of principles, including the way people tend soils, water, plants and animals in order to produce, prepare and distribute food and other goods. These principles are set out in the International Federation of Organic Agriculture Movements (IFOAM) norms for organic production and processing (IFOAM 2006). Organic farming systems tend to rely on crop rotation, crop residues, animal manures and mechanical cultivation to maintain soil productivity, to supply plant nutrients and to control weeds, insects and other pests. While there are many environmental claims that organic agriculture is more beneficial to biodiversity and the environment (Mäder *et al.* 2002; Holzschuh *et al.* 2007), only one study has compared the biodiversity of organisms in organic vs conventionally grown crops in Ireland. O'Sullivan and Gormally (2002) compared carabid beetle communities in organic and conventional potato crops and found a greater abundance (78% higher) and diversity of beetles in the organic plots.

CONCLUSIONS

In the short-to-medium term (0–20 years) agriculture in Ireland will face a number of challenges that will have an unknown impact on farmland biodiversity. These challenges include the reform of the CAP; the introduction of the Nitrate, Phosphate and Pesticide Directives; predicted climate change; a possible switch from food- to energy-crop planting; the potential abandonment of land in some regions of the country; and the possible introduction of genetically modified crop cultivation. In order to measure the impact of these new challenges on Irish biodiversity, baseline data of current levels of biodiversity under existing crop cultivation are necessary.

Publications on many crucial biodiversity aspects of conventional crop cultivation in Ireland are either scarce or non-existent, and many important taxa have never been studied at all. We have been unable to find peer-reviewed studies on the impact of crop cultivation on soil micro-organisms (i.e. bacteria, fungi and protozoa), land mammals and many important insects, such as ladybirds and butterflies, nor any studies on the impacts from the use of integrated pest management as an alternative to conventional pesticide usage. No Irish-based studies have assessed the impact of growing oilseed rape on farmland biodiversity (e.g. on granivorous birds), in a time when acreage planted under rape is expected to increase in the coming years with the removal of sugar beet as the traditional break crop in cereal rotations and the increased interest in rapeseed oil for bio-diesel production.

In agreement with the international literature, there is evidence from our review of the available national literature that conventional methods of crop cultivation have had an adverse impact on the levels of biodiversity on Irish farms, with 15 of the 21 studies to date showing negative trends for the species and groups studied. However, many of these studies found that when more environmentally friendly farming practices are used on arable farms, adverse impacts on biodiversity can be reduced. A few studies listed in Table 1 clearly show the potential benefits of intercropping, minimum tillage, timing of cultivation, set-aside and winter stubble as possible approaches for increasing the biodiversity of the selected indicator taxa examined. Therefore, it is clear that arable farming per se is not detrimental to biodiversity and that in many cases it is likely more biodiversity-friendly farming practices can be devised and applied.

While many studies demonstrate the ecological advantages of the organic farming approach, there are calls for IFOAM-guided organic farming to be subjected to more scientific scrutiny (Trewavas 2004). With just one peer-reviewed publication from Ireland describing the positive impact of organic over conventional farming on carabid beetle abundance and diversity, both farmers and consumers generally rely on anecdotal evidence and data from non-Irish studies; for example, up to 2005 there were at least 76 published UK studies comparing conventional and organic farming (Hole *et al.* 2005). The conclusion from the comprehensive review by Hole *et al.* (2005) was that longitudinal, system-level studies are needed to address knowledge gaps regarding the impacts of organic farming before any full appraisal of its potential role in biodiversity conservation in agroecosystems can be made. Clearly, there is a need to conduct further research on the ecological impacts of organic cropping in Ireland, so that positive claims suggested by the organic industry sector can be substantiated through a comparative assessment against other tillage systems under Irish farming conditions.

The main issues in assessing impacts of arable farming on biodiversity in Ireland are the paucity of baseline data targeting different arable cropping systems (e.g. winter vs spring-sown crops, conventional vs organic, etc.) and the absence of long-term monitoring programmes specifically designed to assess positive or negative effects. While a National Biological Records Centre (NBRC) has now been established by the Irish government, there is, as yet, no comprehensive land-use monitoring system in place that allows changes in the landscape over decades to be investigated. Habitat inventories are largely confined to areas of special conservation concern, such as Natural Heritage Areas or Special Areas of Conservation (Fitzpatrick and Murray 2006). Although the establishment of the NBRC has been a considerable advance, the service it provides should not be considered an appropriate substitute for targeted research on different arable farming practices. A long-term research program, similar to the grassland 'Ag-Biota' project (Purvis *et al.* 2005), needs to be undertaken on arable farms as a matter of urgency. One of the aims of the Ag-Biota grassland-based project was to better identify and alleviate the main farming 'pressures' that may lead to significant biodiversity loss within the Irish countryside. In hindsight, there is little doubt that biodiversity on Irish farms should have been continuously monitored over the last few decades and that this could have been achieved with a fraction of the expenditure spent on the REPS scheme. Therefore, recent funding initiatives such as the EPA's Science and Technology, Research and Innovation for the Environment Programme (up to €100 million between 2007 and 2013, €5.2 million of which will go towards biodiversity research themes) must be welcomed as they provide a mechanism to begin addressing the current knowledge deficit. The onus is now on the Irish research community to capitalise on this opportunity and generate the necessary data sets so that as the Irish tillage industry develops in response to global pressures (e.g. increased energy demands), the concurrent impact on Irish biodiversity is neutralised.

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