RESEARCH TOPIC REVIEW: Wildlife and Biodiversity in Organic Farming: integration and management of farming and wildlife for their mutual benefit

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Contents

1. Scope and Objectives of the Research Topic Review:

This review summarises key research findings regarding the beneficial integration of wildlife and bio-diversity within organic farming. In an ecological and agricultural context bio-diversity would ideally include the diversity of livestock breeds and crop species and varieties, their effect on wildlife habitats, and their role in supporting natural habitats and landscapes. However this subject area is outside the scope of this review and although the presence of such diversity on organic farms will have impacted on the research findings studied, little specific research has been conducted.

The objective of this review is to provide information to advisors, based on peer reviewed research, to increase the scope and abundance of wildlife and bio-diversity on organic farms, with the aim of improving the effectiveness of the organic farming system – *practical and beneficial integration of wildlife, bio-diversity and organic farming.*

By 2008 the majority of organic farms in the UK were relatively new to organic farming, having been encouraged to register as organic because of either beneficial market opportunities or agri environment programmes encouraging conversion. Clearly a proportion of farmers have entered organic farming with a good understanding of the farming system but many are still operating relatively conventional systems organically without in depth understanding of the principles and foundations of organic farming. The agri-environment schemes that encourage and support organic farming have been developed from schemes designed largely to encourage intensive chemical based farming to adopt some beneficial practices. The organic schemes tend to adopt similar prescriptive practices rather than encourage a completely holistic approach and the result is that farmers often fulfil environmental prescriptions to gain points rather than understanding how habitat management can work in harmony with, and improve the farming system.

Number of organic and in-conversion producers in the UK, 1997-2007

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
828	1064	1568	2865	3691	3865	4104	4017	4010	4343	4639

(Source: *Organic Food and Farming Reports 1997-2007*)

Organic agriculture is based on the following 4 principles (taken from IFOAM):

1. The principle of health
2. The principle of ecology
3. The principle of fairness
4. The principle of care

All 4 principles are inter-linked but the key principle that relates to the integration of wildlife, habitats and farming is the principle of ecology. An explanation of this principle is as follows:

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling. Nourishment and well-being are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil; for animals it is the farm ecosystem; for fish and marine organisms, the aquatic environment.

Organic farming, pastoral and wild harvest systems should fit the cycles and ecological balances in nature. These cycles are universal but their operation is site-specific. Organic management must be adapted to local conditions, ecology, culture and scale. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources.

Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

Through its holistic nature organic farming aims to integrate wild biodiversity, agro-biodiversity and soil conservation, and takes low-intensity, extensive farming one step further by eliminating the use of chemical fertilizers, pesticides and genetically modified organisms (GMOs), which is not only an improvement for human health, but also for the fauna and flora associated with the farm and farm environment.

This review summarises the research that has been completed and which is relevant to conditions in the UK and the draws conclusions and recommendations from that research.

2. Summary of Research Projects and Results

Anon, (2005) *Factors influencing biodiversity within organic and conventional systems of arable farming (OF0165).* Report, British Trust for Ornithology.
Wildlife data was collected from 2000 to 2003 from 89 organic farms in England and compared with data from non-organic farms within the vicinity of each organic farm (mostly within 10 km).

Abundance: there were 109% more plants within the crop, 32% more birds, 16% more spiders (average of boundary and crop data) and 35% more bats. Of 30 bird species analysed, 15 were more abundant on the organic farms.

Diversity: there were 85% more plant species in the cropped area of organic farms (35 species vs. 19 on non-organic), 17% more spider species in the cropped area and 33% more bats.

Features of organic farms affecting biodiversity:

Organic fields are 32% smaller on average (7.3ha compared to 10.7ha) and there is an average of 50% more boundary length per unit area on organic farms (150m per ha compared to 100m per ha on non-organic). Organic farms had better hedge habitats which is important for invertebrates, birds and bats: 71% more hedge length, larger (wider and taller), cut less frequently and more likely to be traditionally layed. There was no significant difference in the numbers of hedge species.

Organic farms have a much higher proportion of grassland (38% of the land is grass compared to only 17% on the non-organic farms). 58% of the organic farmland was arable, compared to 70% of the non-organic. There was also more non-cropped habitat (important for birds) and open water (important for bats) in the wider landscape around organic farms

Other factors which the researchers identified from the farmer questionnaires that are "likely to influence biodiversity": organic farmers sow their crops later in all three years (eg. to avoid the weed flush in winter cereals).

The rotations were different. The organic rotations always included a grass ley as part of a cereal/vegetable rotation. Conventional farmers had a break crop or vegetables or set-aside in a cereal rotation.

No organic farmers cropped continuously but 22% of the non-organic farmers did.

Many organic farmers undersowed their spring cereals with a ley, but none of the conventional farmers did.

More likely to include livestock (important for bats), had a greater variety of livestock and were more likely to graze them on the arable land (eg. on the stubble or during the leys).

All non-organic farmers used fertilisers.

Weediness had a significant impact on invertebrate abundance and diversity.

More likely to be in an agri-environment scheme other than the Organic Farming Scheme (64% compared to 43% for non-organic farmers).

Set-aside management - organic farmers were less likely to use the natural regeneration option, and twice as many used *no* set-aside. No difference in use of rotational or permanent set-aside.

The researchers suggested that the potential of organic farms to support animals wildlife? is actually far greater, and that the biodiversity benefits are held back because organic farms are relatively small "isolated units" in an intensively managed landscape.

Stoate, C., Whitfield, M., Szczur, J., Williams, P., & Driver, K. (2007). Multifunctional benefits of an agri-environment scheme option: Riparian buffer strip pools within 'Arable Reversion'. *Aspects of Applied Biology*, 81: 221-226.
This study assessed the dual benefits of riparian buffer strip pools in arable land for watercourse quality and biodiversity. It was found that the pools, fed by arable field drains and ditches, reduced the concentrations of N and P and the sediment load entering watercourses. In particular, the phosphorus content in the pools was 40-50% lower than in the supplying ditch. With respect to

biodiversity, the pools supported amphibians and a wide number of invertebrate species, and provided birds with insect food and a breeding habitat. Whitethroat and reed bunting numbers increased (they had higher nest survival rate in this habitat compared to field boundaries) and the area was used by lapwing and yellow wagtail in summer and mallard and snipe in winter.

Stoate, C. & Moorcroft, D. (2007). Research-based conservation at the farm scale: Development and assessment of agri-environment scheme options. *Aspects of Applied Biology*, 81: 161-168.
Within a non-organic farming system, case study habitats were investigated for their impact on farmland birds.

Skylark plots: While acknowledging that spring sown crops are better for breeding skylarks, this study provided a method to improve breeding productivity within autumn sown crops. Leaving 4m x 4m undrilled areas every half hectare resulted in 49% more young than in winter wheat without the plots, as the breeding season was lengthened by the availability of invertebrate food. Replicated trials on 26 commercial farms within the SAFFIE projected have confirmed the results (Ogilvy et al, 2006).

Beetlebanks: Provide overwintering habitat for beneficial invertebrate predators of aphids in field centres, with cocksfoot and false oat grass best for beetles, Yorkshire fog and meadow foxtail good for lesser marsh grasshoppers. Cocksfoot was also identified as beneficial to nesting harvest mice due to its structural support and use as nesting material.

[Ogilvy *et al* (2006) Research into practice and policy, *Arable protection in the balance: Profit and the environment, Proceedings of home grown cereals authority R&D Conference 2006, London: HGCA]*

Kragten, S., G. R. De Snoo. Nest success of lapwings *Vanellus vanellus* on organic and conventional arable farms in the Netherlands. Ibis (2007) 149, 742 – 749
It was found that territory densities of lapwings were generally higher on organic than non-organic farms (related to the greater food abundance), but that nesting success was not always better compared to minimum tillage fields. Results indicated that a higher frequency of soil-disturbing farming activities, such as tillage and mechanical weeding, leads to greater nest failure rates of ground-nesting birds. In the Netherlands, volunteers participating in nest protection projects on farms have succeeded in increasing lapwing hatching success.

Rundlof, M. H. G. Smith. The effect of organic farming on butterfly diversity depends on landscape context. Journal of Applied Ecology (2006) 43, 1121-1127
Butterfly species richness and abundance along cereal field headlands and margins were compared in 12 matched organic and conventional farm pairs in homogeneous or heterogeneous landscapes. Both organic farming and landscape heterogeneity significantly increased butterfly species richness and abundance. However, the interaction of farm management and landscape type was such that organic farming increased butterfly species richness and abundance in homogeneous rather than heterogeneous landscapes. It was proposed that organic farming methods such as a long and diverse crop rotation scheme with a high proportion of leys promotes butterfly diversity and abundance by increasing the number of temporary food sources. Landscape heterogeneity, with areas of semi-natural grassland, was suggested as important to provide permanent habitat as opposed to the temporary habitat of annual crops, and support species that have different habitat needs during different life stages. In an otherwise homogenous landscape, organic farming may recreate some of this heterogeneity necessary for biodiversity.

Holzschuh, A., I. Steffan-Dewenter, D. Kleijn and T. Tscharntke. Diversity of flower visiting bees in cereal fields: effects of farming system, landscape composition and regional context. Journal of Applied Ecology (2007) 44, 41-49

Conducted in German wheat fields, this study investigated the impact of organic farming and landscape heterogeneity on species diversity of bees, important both for their pollination services and their intrinsic biodiversity value. Flower cover and diversity of flowering plants were positively related to bee diversity, and organic farming was the variable with the biggest positive effect on bee diversity. Results indicated that above a certain threshold of plant diversity (exceeded by all organic, but not conventional, farms in the study), higher flower cover continues to benefit bee diversity. The highest relative impact of organic farming on bee diversity was greatest in homogeneous landscapes, as residual bee diversity increased with landscape heterogeneity. The authors concluded that organic arable farming could help to sustain pollination services by generalist bees in agricultural landscapes, but an increase in semi-natural habitat would be required to conserve more specialized bee species.

Clough, Y., A. Kruess and T. Tscharntke. Local and landscape factors in differently managed arable fields affect the insect herbivore community of a non-crop plant species. Journal of Applied Ecology (2007) 44, 22-28

This German study investigated the determinants of the non-crop plant-based insect communities within arable fields, in order to extrapolate plant diversity benefits to ecosystem services such as pest predation and pollination provided by the above-ground food chain. The effect of agro-ecosystem diversity at the field and landscape level was studied through the monitoring of arthropod diversity on plots of creeping thistle. Herbivore species richness was enhanced by both organic farming and landscape heterogeneity (fewer arable crops, more perennial habitats). Organic plots were more likely to be colonised by most species than those in conventional fields. It was concluded that since the biodiversity benefits of organic farming rely for a large part on non-crop plants, weed populations should be allowed to coexist with the crop through a reduction of the more 'intensive' organic management practices such as heavy mechanical weed control. At a landscape level, the maintenance of a minimum level of perennial habitat cover would be beneficial.

Hutton S.A.; Giller P.S. (2003). **The effects of the intensification of agriculture on northern temperate dung beetle communities, *Journal of Applied Ecology,* Volume 40, Number 6, pp. 994-1007(14).**

As dung beetles are essential for the recyling of organic matter and plant nutrients from dung into the soil, and thus for the maintenance of quality grazing pasture, this study investigated the effect of farm management practices on the dung beetle community.

Abundance, biomass, richness and diversity of dung beetle species was higher on organic than on intensive and rough grazing farms, and dung from organic farms was colonised with a greater beetle biomass. Intensive farms were shown to support 38% fewer dung beetle species than organic farms, an indication of biodiversity loss in keeping with the finding of Rushton et al (1986) that species composition and diversity of ground beetles and spiders decreased when upland pastures were agriculturally improved.

Field boundaries of organic farms were more diverse and provided cover for shade specialists – those organic farms with the highest vegetative cover also had the highest number of these specimens. Sites prone to flooding were problematic for dung beetle populations, and disproportionately so for some of the larger species that are important for their substantial dung breakdown potential. In keeping with previous literature on the negative effects of vetinerary medicines for endoparasite control on dung beetle populations, there was a clear reduction in second generation numbers of certain species on sites that had administered ivermectin, compared with those that did not.

Patchy ecosystems characterised by open pasture and dense surrounding vegetation and inhabited by several ungulate species (i.e. cattle, horses and sheep) were identified as supporting the highest levels of dung beetle diversity, abundance, biomass and species richness and hence improving dung decomposition and pasture quality

Purtauf, T., I. Roschewitz, J. Dauber, C. Thies, T. Tscharntke, V, Wolters. Landscape context of organic and conventional farms: influences on carabid beetle diversity. (2005). Agriculture, Ecosystems and Environment. 108, 165-174

Carabid species richness and density, important for biocontrol, were studied in 12 pairs of organic vs conventional wheat fields in Germany, along a gradient of landscape complexity. It was found that the most significant factor in both species richness and activity density was the percentage of grassland cover in the surrounding landscape, irrespective of management type, suggesting that grassland can act as a source of diversity by offering refuges and corridors for beetles dispersing across and between fields. Spring breeders were found to benefit particularly from landscape diversity as they require overwintering sites in which to hibernate as adults before migrating into the fields. There was higher activity density of spring breeders found in organic compared to conventional fields, but only in landscapes with high levels of grassland, implying that given good overwintering habitat, those in organic fields were in better condition due to the greater availability of food.

Liat P. Wickramasinghe, Stephen Harris, Gareth Jones and Nancy Vaughan (2003) Bat activity and species richness on organic and conventional farms: impact of agricultural intensification, *Journal of Applied Ecology*, Volume 40, Issue 6, Page 984-993

Bat activity and species richness were compared on matched pairs of organic and conventional farms. On organic farms, total bat activity was higher, there was more bat activity over water, foraging activity was higher, and there was activity of a wider number of species.

Results supported the hypothesis that the significantly higher hedgerow height on organic farms contributed to the higher bat foraging activity on these farms, as they provide linear flight paths and shelter belts for insect food. Water habitat is important for bats, and the higher bat activity over organic water habitat was attributed to higher water quality that supported a greater diversity of insect species.

Wickramasinghe, L. P. Harris, S. Jones, G. Vaughan Jennings, N. Abundance and species richness of nocturnal insects on organic and conventional farms: effects of agricultural intensification on bat foraging. Conservation Biology 18 (2004) 1283 – 1292

To explain the greater general and foraging activity of bats on organic farms, this study investigated the effect of farm management on their prey. Nocturnal and crepuscular aerial insect abundance and species richness were higher on organic farms than their conventional counterparts. This was attributed to: the lack of agrochemicals; higher plant species richness and plant functional-group richness; lower grazing intensity; more structurally varied habitats; less use of antihelminthic drugs such as avermectin (which reduce the insect fauna in dung that provide food for bat prey); better water quality; and the fact that riparian habitats on organic farms are more often surrounded with trees and bushes that provide shelter and dead leaf beds for varied insect groups.

Aude, E., K. Tybirk, A. Michelsen, R. Ejrnaes, A.B. Hald, S. Mack. Conservation value of the herbaceous vegetation in hedgerows - does organic farming make a difference? Biological Conservation 118 (2004) 467 - 478

The study compared hedgerows on organic and conventional farms in Denmark, finding that organic hedgerows significantly more species and had showed a species composition more similar to semi-natural habitat. This was due to the higher numbers of weedy species, open semi-natural species and bryophytes.

Pfiffner, Lukas; Merkelbach, L. and Luka, Henryk (2003) Do sown wildflower strips enhance the parasitism of lepidopteran pests in cabbage crops?. *International Organisation for Biological and Integrated Control of Noxious Animals and Plants/West Palaearctic Regional Section Bulletin* 26(4):pp. 111-116

To assess the potential of wildflower strips to enhance biological control of pests, the parasitism rates of cabbage lepidopteran pests were investigated in fields with or without sown, species-rich wildflower strips. It was found that the strips enhanced the diversity and abundance of parasitic wasps and that the parasitism rate of pest caterpillar eggs increased with proximity to the strip. It was suggested that a mix of species to create a long-flowering strip would be particularly effective for biological control through parasitoids as they rely on sugar sources such as nectar, honeydew and pollen for longevity and high searching activity. Within annual crops, perennial and undisturbed habitats are necessary for successful conservation of parasitoids and predators.

Langer, Vibeke (2001) The potential of leys and short rotation coppice hedges as reservoirs for parasitoids of cereal aphids in organic agriculture. *Agriculture, Ecosystems and Environment* 87:pp. 81-92

This study assessed whether leys used for nitrogen-fixing and fodder and short-rotation coppicing used for energy had potential as reservoirs for parasitoids that attack cereal aphids. It was found that SRC hedges and clover/grass leys in the rotation increased diversity and activity of parasitoids attacking cereal aphids, with different species active at different times. The potential for natural regulation of cereal aphids in the system is therefore increased by the presence of undisturbed crops in the rotation and the presence of semi-natural elements. It is suggested that the more recent practice of undersowing green manures which are disturbed annually is problematic for parasitoid communities, as tillage kills the overwintering parasitoid mummies present in the crop.

Roschewitz, I. D. Gabriel, T. Tscharntke, C. Thies. The effects of landscape complexity on arable weed species diversity in organic and conventional farming. Journal of Applied Ecology (2005) 42, 873-882

It was found that overall diversity of arable weed species was determined by high heterogeneity between and within fields. Weed species diversity in the vegetation, seed rain and seed bank was higher in organic than conventional fields. However, increasing landscape compexity enhanced species diversity more strongly in the vegetation of conventional than organic fields to the point that the level was similar between the two systems when the complexity of the surrounding area provided refuge for weed populations. Since organic farms contributed most effectively to weed species diversity in simple landscapes, it was suggested that conversion of conventional farms to organic in such areas should be incentivised.

Aquilina, R., Williams, P., Nicolet, P., Stoate, C., & Bradbury, R. (2007). Effect of wetting-up ditches on emergent insect numbers. *Aspects of Applied Biology*, 81: 261-262

This study investigated the effect of damming up sections of agricultural ditch on the insect populations, with the aim to increase insect food for farmland birds. The bunded areas retained water longer and yielded significantly greater biomass than the controls. The average production of emerging insects was 150% higher (dry mass) in the bunded areas than the controls, with variation across species.

Griffiths, G.J.K., Winder, L., Holland, J.M., Thomas, C.F.G., & Williams, E. (2007) The representation and functional composition of carabid and staphylinid beetles in different field boundary types at a farm-scale. *Biological Conservation*, 135: 145-152

At field boundaries, hedgerows, degraded hedgerows and fences were sampled for overwintering carabid and staphylinid beetles. It was found that each boundary type supported unique species not found elsewhere and that all field boundary types were equally important for full representation of species at the farm-scale. Biological control was best provided by the grassy/herbaceous vegetation associated with fences, though this could be reproduced adjacent to pre-existing hedgerows.

Hedgerows supported a large number of unique species, though woodland species were not more evident here despite the similarity of habitat. Degraded hedgerows supported species with poor dispersal powers vulnerable to disturbance, with the implication that hedgerow restoration may benefit some insect communities at the expense of other rare taxa that may be unable to recolonise disturbed sites. It is suggested that habitat heterogeneity, spatiotemporal diversity in management type and a more precautionary approach to habitat restoration would best enhance farmland biodiversity, with the benefit of cross-taxon ecosystem services.

Fowler, Susan; Frost, David and de Carle, Caroline Fowler, Susan, Eds. (2004) *Environmental and biodiversity impacts of organic farming in the hills and uplands of Wales*. Report, Organic Centre Wales

This report aimed to address the practices that may benefit biodiversity in hill and upland organic farming. The practices on organic livestock farms identified that may differ from conventional and have direct biodiversity or environmental impacts were: lower stocking rates (overall manure loading maximum of 170kg/N/ha/yr); mixed stocking; an adjustment of the stocking balance (increasing ratio of cattle to sheep); keeping indigenous breeds and strains adapted to the environmental conditions on the farm; use of multi-species swards; limitation on products to control external parasites (to avoid negative impact on dung beetles in particular); reduction and restriction on the use of prophylactic veterinary medicines; the use of foragebased diets; storage and use of slurries, manures and composts, and constraints on the import and export of nutrients.

Keatinge, R (2005) *Organic production in the hills and uplands (OF0319)*. Report, Redesdale, ADAS Consulting Ltd.

Relevant findings were that long-term studies of vegetation change on native hillside showed a continuing decline in heather cover at the higher stocking rates. Where stocking rates were reduced significantly to accommodate a more balanced organic system there were indications of a positive, albeit slow response in botanical composition. Key to this was the ability to manage moorland in a more pro-active way, and to have cattle available to graze Molina and Nardus. This complimentary effect of cattle not only controls the competitive effects of these grassy species with heather, but as demonstrated in other research, also benefits sheep performance. With regard to dock control on organic in-bye fields, it was suggested that a fallow period followed by grazing by pigs could have good potential.

Clements, R (2002) Clover:cereal bi-cropping for organic farms (OF0173), Report, Institute of Grassland and Environmental Research

Direct drilling of cereal crops into an established understorey of white clover has shown success in non-organic farming systems by reducing the need for agro-chemical inputs. The benefits from clover:cereal bi-cropping are listed as: simultaneous cropping and fertility building; effective nutrient cycling; weeds replaced by clover, reducing need for weed control; confusion of insect pests and habitat for beneficial insects; limits spread of fungal foliar diseases; improved field access relative to bare soil. However, grass weeds are a problem in the organic bi-cropping system due to the lack of herbicide and this study aimed to adjust the clover:cereal approach for success in organic farming. Results from field trials revealed two possible strategies. Firstly, oats appeared to suppress grass weeds and growing this crop instead of wheat may be a solution. Secondly, strip drilling alternate 20cm strips of cereal with 30cm strips of clover facilitates weed control by allowing separate management of the two crops. It was suggested that a rotational integration of these two strategies may bring benefits. A clear advantage of the system was the absence or very low levels of pests and diseases despite high levels of airbourne pathogens in the area. It was theorised that the bi-cropping system could have contributed to this through: restricting the spread of spash-bourne diseases due to presence of clover around the cereal plants; green background confusion of insect pests; a lack of surplus soluble nitrogen in the cereal plants. However, the system is not viable for spring sown crops as they are easily out-competed by the clover.

Hole, Perkins, Wilson, Alexander, Grice and Evans (2005) 'Does organic farming benefit biodiversity?', *Biological Conservation*, 122, 113-130
This paper includes the following comprehensive review of the biodiversity impacts of common organic farming practices, covering all the literature up until 2004. To avoid repetition, the individual projects to which the review refers will not be covered separately elsewhere in this PACARes.

Mechanical weeding
Involves the dragging of tines or hoes across the soil surface to remove young weeds (Pullen and Cowell, 1997).

Often less efficient than using herbicides (Krooss and Schaefer, 1998) - contributes to a greater abundance of non-crop flora in arable fields, indirectly supporting higher densities of arthropods (Kromp, 1989, 1999).

Can be highly effective under certain conditions (Pullen and Cowell, 1997) extensive use may lead to the decline of long-lived winter annuals and support of short-lived summer annuals, potentially leading to a more impoverished weed flora (van Elsen, 2000).

May cause high mortality amongst eggs and chicks of ground-nesting bird species (Hansen et al., 2001) unless carefully timed.

Farmyard and green manuring
Animal waste and green manures (i.e. the ploughing in of specific unharvested crops))used to replace nitrogenand other elements and to build up soil organic matter content (Lampkin, 2002).

Generally supports a greater abundance of invertebrates that rely on un-degraded plant matter as a food source, e.g. earthworms (Gerhardt, 1997; Pfiffner and Mader, 1997), carabids (Kromp, 1999), and more diverse microbial communities (Fraser et al., 1988).

Can result in insufficient input of nitrogen into organic systems) leads to poor crop and weed growth, the development of an unfavourable microclimate and a depauperate invertebrate community (Brooks et al., 1995; Krooss and Schaefer,1998).

Minimum tillage
Involves the use of discs or tines to disturb the soil surface without physical turning of the soil (Lampkin, 2002)

Avoids detrimental effects of inversion ploughing (physical destruction, dessication, depletion of food and increased exposure to predators (Stoate et al., 2001) on invertebrate populations; e.g. earthworms (Gerhardt, 1997; Higginbotham et al., 2000); spiders (Haskins and Shaddy, 1986); collembola (Alvarez et al., 2001) and other macrofauna (Krooss and Schaefer, 1998).

May negatively impact carabids)often found in greater abundance on ploughed fields (Baguette and Hance,1997).

May modify floral community (McCloskey et al., 1996) - minimum tillage tends to favour annual weeds (Albrecht and Mattheis, 1998; Cousens and Moss, 1990) whilst perennial broad-leaved weeds are more common under ploughed regimes (Frick and Thomas, 1992; Higginbotham et al., 2000), as a result of variations in seed longevity and species-specific germination patterns.

Effects on vertebrates are largely unknown) some evidence that minimum tillage may benefit bird communities (Lokemoen and Beiser, 1997; McLaughlin and Mineau, 1995).

Intercropping and undersowing
Both can be used in a rotation to suppress weeds (Baumann et al., 2000) and increase crop yields (Fukai and Trenbath, 1993).

Undersowing increases vegetation structure and heterogeneity)enhances invertebrate populations; e.g. sawflies (Hymenoptera: Symphyta), carabids and spiders (Helenius et al., 1995; Potts, 1997; Sunderland and Samu, 2000); provides a greater abundance of invertebrate food resources for birds and mammals, e.g. grey partridge (Ewald and Aebischer, 1999; Potts, 1997) and corn bunting (Brickle et al., 2000).

Subsequent over-winter crop stubbles may provide only limited seed accessibility to granivorous birds as a result of a reduction in the area of exposed soil (Moorcroft et al., 2002)

Effects of intercropping on biodiversity are largely unknown - increase in heterogeneity may favour increased invertebrate diversity; e.g. polyphagous predators (Altieri and Letourneau, 1982; Sunderland and Samu, 2000).

Sensitive field margin/ hedgerow management/ creation of non-crop habitats
Actively encouraged by organic standards to bolster natural predator populations (e.g. Soil Association, 1999).

Establishment of field margins and beetle banks) develops and supports larger, more diverse invertebrate communities (de Snoo, 1999; Haysom et al., 1999; Moreby et al., 1994; Thomas et al., 2002); e.g. predatory beetles (Lys and Nentwig, 1994); provides overwintering sites and refuges following harvest (Frieben and Kopke, 1995; Gluck and Ingrisch, 1990); supports a more diverse arable flora (Wilson and Aebischer, 1995); provides important nesting and feeding habitat for birds; e.g. yellowhammer (Bradbury et al., 2000; Morris et al., 2001), grey partridge (Rands, 1985, 1986), whitethroat Sylvia communis (Eaton et al., 2002) and a variety of small mammals (Smith et al.,1993)
Positive hedgerow management - reduced herbicide spray drift (prohibited in organic systems) prevents impoverishment of hedge bottom (Aude et al., 2003; Jobin et al., 1997; Kleijn and Snoeijing, 1997); results in greater floral diversity and increased invertebrate populations (Boatman et al., 1994); greater width and structural diversity is positively associated with abundance and species richness of breeding birds (Green et al., 1994; Hinsley and Bellamy, 2000; Parish et al., 1994, 1995); provides sheltering habitat for mammals; e.g. brown hare Lepus europaeus (Tapper and Barnes, 1986).

Hedgerows and other non-crop habitats provide dispersal corridors and islands in otherwise fragmented landscapes, facilitate dispersal of; e.g. many bird species (Hinsley and Bellamy, 2000), mammals (Fitzgibbon, 1997; Tew et al., 1994) and beetles (Holland and Fahrig, 2000).

Some bird species favour shorter hedgerows; e.g. whitethroat (Eaton et al., 2002) and linnet (Moorcroft, 2000); skylark and lapwing avoid tall boundary structures (O_Brien, 2002; Wilson et al., 1997).

Small field size
Requirement for stock-proof boundaries in conventional mixed and organic systems is likely to result in smaller average field size than on specialist arable farms (e.g. Chamberlain and Wilson, 2000).

Evidence suggests small fields support greater biodiversity per unit area (principally as a result of a higher percentage of non-crop habitat separating individual fields) - abundance and diversity of carabids, spiders and arable flora decreases with distance from field margins (Frieben and Kopke, 1995; Hald, 1999; Jmhasly andNentwig, 1995; Kay and Gregory, 1998, 1999; Kromp, 1999); large fields support less diverse spider communities (Basedow, 1998; Gluck and Ingrisch, 1990); density of brown hares is higher on farms with smaller fields (Tapper and Barnes, 1986)

Spring sown cereals
Delayed development of spring-sown cereals (in comparison to autumn-sown) produces shorter, less dense crops in early and mid-season)preferred breeding and foraging habitat for a number of bird species; e.g. skylark (Donald et al., 2001b; Wilson et al., 1997), lapwing (Galbraith, 1988) and corn bunting (Brickle et al., 2000).

Spring sowing frequently results in stubble fields being left over part or all of the winter) allows spring germinatingannual weeds to set seed and germinate; e.g. cornflower, red hemp-nettle Galeopsis angustifolia (Stewart et al., 1994) and corn marigold Chrysanthemum segetum (Wilson and Sotherton, 1994); provides a crucial winter food source (i.e. weed seed and spilt grain) for seed-eating birds (Donald and Evans, 1994; Evans, 1997; Wilson et al., 1996); e.g. corn bunting (Brickle et al., 2000), cirl bunting (Evans and Smith, 1994).

Crop rotation
Involves the planting of a sequence of crops, including a grass ley (often undersown into the previous crop).

Used primarily to control weeds and other pests/diseases; also to enhance soil fertility via the inclusion of a legume (e.g clover in the grass mix) (Lampkin, 2002; Liebman and Dyck, 1993; Stoate, 1996).

Presence of a grass-clover ley) significantly enhances populations of non-pest butterfly species (Feber et al.,1997); undersowing encourages invertebrate populations (see above).

Increased crop diversity may benefit a variety of species that require a structurally diverse crop/habitat mosaic; e.g. skylark (in order to make multiple breeding attempts) (Wilson et al., 1997), lapwing (require adjacent cereal and pasture) (Galbraith, 1988; Tucker et al., 1994), brown hare (graze a variety of crops at different times of the year) (Tapper and Barnes, 1986).

Mixed farming
The occurrence of arable fields in close juxtaposition with pastoral elements is likely to have significant benefits for biodiversity across a range of taxa - increases habitat heterogeneity at multiple

spatial and temporal scales (Robinson et al., 2001; Stoate et al., 2001; Vickery et al., 2001; and see Benton et al., 2003 for a review).

3.0 Analysis and Conclusion

3.1 Introduction

There has been a significant amount of research completed in the area of wildlife and bio-diversity impacts of organic farming. Much of this has compared the differences in mammal, bird, insect, and plant populations between organic and non organic, while some goes further by identifying the specific practices within organic systems that make a difference. There is a limited amount of research that has truly explored mutually beneficial relationships between wildlife, biodiversity and agricultural production, with most of any work done concentrating on pest and predator relationships regarding crop production. There is a need for further research into relationships between wildlife, habitats and livestock management (particularly in relation to disease and parasites). Associated with this is an acute shortage of research into mutually beneficial farming and wildlife management in upland areas.

However there has also been much wildlife and bio-diversity research conducted on an EU and UK level that while not specific to organic, can be relevant.

While more research work needs to be done into beneficial relationships, namely pest/predator relationships, right across the farming spectrum, it is accepted that a holistic and well balanced eco-system is essential for its own maintenance, and that a vibrant ecology has a beneficial relationship with organic farming. Arguments can be made that particular species have a negative effect on farming – for instance badgers are linked with bovine TB, and mole workings can damage machinery and cause soil contamination of silage, but take any one link out of the ecological chain and it will impact elsewhere. It is also clear that modern farming practices have impacted hugely on wildlife and biodiversity, in many cases resulting in problems elsewhere. For instance the increase in badger numbers has been assisted by the expansion of maize as a fodder crop, and silage is affected by soil contamination (listeria) whereas hay is unaffected. Sometimes human intervention into wildlife control and support is necessary but this should always be done with ecology as a whole in mind.

3.2 Farm structure and factors leading to biodiversity

The farm structure of organic farms generally offers much potential for increased biodiversity and in return improved biodiversity is beneficial to the functioning of the organic system. Enhancing the structure of the organic farm can provide additional benefits, and there is potential for improvements to farm structure and habitats to be funded through agri environment programmes.

Beneficial farm structure factors include:

- Smaller fields and increased boundary lengths
- Corridors of wildlife habitat
- Hedges, field walls, field margins, beetle banks
- Hedges and ditches managed in rotation with differing growth stages
- ‘Mosaics’ of hedge management
- Permanent grassland and rotationally cropped areas
- Water habitats
- ‘Pooled/tiered’ water systems
- Woodland and other non cropped habitats
- Building soil biomass and organic material
- Mixed cropping and livestock – wide enterprise mix

Additional beneficial factors include:
- Reductions in mechanical operations
- Late sowing of spring crops
- Undersowing of spring cereals with leys
- Multi species grass ley mixtures and use of clovers and herbs
- Acceptance of non invasive weeds (weeds should be allowed to co-exist)
- Balance of spring and autumn cropping

3.3 Bird specific factors

'A study looking at the territorial densities of lapwings (Kragten et al, 2007) discovered that this was generally higher on organic than non – organic farms which was found to be related to a greater abundance of food. Results also indicated that a higher frequency of soil disturbance farming activities, such as tillage and mechanical weeding, causes greater nest failure rates of ground nesting birds'.

These findings demonstrate that birds, as with most living creatures, require habitat (somewhere to live, hide, roost, nest), and food sources. No research has been identified which demonstrates beneficial relationships between birds and pest control, however birds do perform a pest control role - rooks and slugs/leatherjackets, thrushes and slugs/snails, and birds also help break down animal manures while foraging for dung related invertebrates. Birds can also create problems (rooks on ripe barley or freshly sown fields) and their presence needs managing periodically. Consideration should be given to the requirements of different species and seasonal needs including:

- Active soil life
- Rotational cropping providing differing habitats and nesting and feeding opportunities
- Mechanical operations to avoid nest or chick destruction (justify and time mechanical weeding, avoid frequent operations, plan operations such as harvesting and mowing to allow for 'escape routes')
- Field boundary management to encourage insects for chick feeding
- Avoid heavy stocking at sensitive times on nesting sites
- Hedge cutting to maximise winter feeding opportunities
- Consider supplementary winter feeding of weed seeds and tailings
- Consider nesting and roosting opportunities (nest boxes, dead trees, access to buildings where appropriate)
- Access to water habitats assists feeding opportunities
- Wet areas and mud for nesting (particularly swallows and house martins)
- Consider predator impact (cats, magpies, foxes) and act sensitively.

3.4 Insect specific factors and beneficial pest/predator balances

Insects are important in their own right and also perform a crucial link in the ecological food chain. The diversity of habitat and the avoidance of pesticides found on organic farms is beneficial for insects. Creating the right habitats and conditions for a broad range of insects is possibly the best researched factor in establishing a beneficial pest/predator balance in the case of crop pests.
For further improvements consider:

- Promote active soil life and feed soil with compost, manures and green manures
- Provide a patchwork of species rich and semi natural grassland areas
- Diverse ley mixtures and use of herbs and wildflowers (beneficial for both livestock and insects)
- Use wildflower strips and ensure long flowering periods by species mix
- Allow herbs/flowers to flower and seed
- Late hay cutting

- Rotational hedgerow and tree management to allow for species variation
- Crop and non crop management to allow migration and movement of insects
- Leave some dead wood
- Diverse habitats for breeding and overwintering of insects (natural and artificial)
- Allow sufficient undisturbed habitat for pest predators (hedgerows, long grass, beetle banks)
- Beetlebanks including coarse grasses such as Cocksfoot and Yorkshire fog
- Avoid annual destruction of all green matter
- Large areas of landscape not treated with pesticides
- Unimproved pastures grazed by livestock
- Cattle grazing and avoidance of Ivermectin treatments
- Provide regular water habitats for insects and amphibians

3.5 Bat specific factors

Organic farms have been shown to be beneficial to bat populations due to increased habitat and feeding opportunities. Bats feed mainly on flying insects and perform a valuable function in keeping insect populations in check. Consider:

- Rotational hedgerow management and a proportion of high hedges
- Standing dead trees
- Water habitats for overhead insect foraging by bats
- Species richness of pastures and non cropped habitats such as field margins and beetle banks
- Grazing livestock
- Access to and maintenance of roost sites in buildings – maintain access and exit points

3.6 Farming practices

Farming practices can impact significantly on the success or otherwise of successful relationships between wildlife and biodiversity and organic farming. Consider the impact of the following practices:

Mechanical weeding:

- Can cause high levels of mortality in ground nesting birds
- Choose crop varieties that compete naturally against weed competition
- Assess fields and conditions to justify weeding operations and only weed when necessary
- Weed areas of fields to need, rather than whole fields
- Avoid too frequent weeding (ideally weed just once, but avoid weeding within 30 days)
- The wider the weeder the fewer the wheel marks

Farmyard manures, composts, and green manuring:

- Hugely beneficial in building soil organic matter and micro-organisms
- Supports wide range of invertebrates
- Consider destruction of green manures outside nesting periods
- Avoid nutrient run off and pollution of valuable water habitats

Minimum tillage:

- May support earthworm and spider populations
- Avoid minimum tillage that results in additional continuous mechanical operations
- Any benefits of minimum tillage needs to be balanced with rotational requirements, weed control and soil structure

Intercropping and undersowing:

Defined as 'Sowing different plant communities in the same field at the same time as/ later than the 'cash crop''.

- Undersowing of crops with plants such as trifoleum can help weed control as well as provide fertility for the crop and habitat for mammals birds and invertebrates
- Allow undersown crops such as trifoleums to flower if possible
- Increases vegetative structure and enhances food sources for birds and invertebrates
- Intercropping of plant species (eg onions, marigolds and carrots) can both attract pest predators and discourage pests

4 Further research needs

The following needs for further research have been identified:

- Beneficial relationships between natural organisms/biodiversity and livestock health/disease
- Optimum wildlife populations and their effectiveness in maintaining a mutually beneficial relationships
- Upland biodiversity implications of organic farming

5. References

Alexander I: Biodiversity and organic farming – where next after Curry (2002) Organic Research Conference, Aberystwyth

Alfoeldi et al : Organic agriculture and the environment. *(2002) FAO Environment and natural resources series 4*

Anon: Factors influencing biodiversity within organic and conventional systems of arable farming. (2005)
Report no OFO 165 British Trust for Ornithology

Aquilina R, Williams P, Nivcolet P, Stoate C, Bradbury R: Effect of wetting upditches on emergent insect numbers. *(2007) Aspects of applied Biology 81: 261-162*

Aude E, Tybirk K, Michelsen R, Ejrnaes R, Hald A B, Mack S: Conservation value of the herbaceous vegetation in hedgerows – does organic farming make a difference? *(2004) Biological Conservation 118: 467 -478*

Clements R: Clover:cereal bi-cropping for organic farms. *(2002) Report No OFO 173 Institute of Grassland and Environmental Research, North Wyke*

Clough Y, Kruess A, Tsharntke T : Local and landscape factors in differently managed arable fields affecting the insect herbivore community of a non- crop species. *(2007) Journal of Applied Ecology 44: 22-28*

Eekeren et al., Analysis of the soil food web under structure under grass and clover. *(2005) Paper presented at*
Cost Action 852 , Grado , Italy

Fowler S, Frost D, de Carle C: Environmental and biodiversity impacts of organic farming in the hills and uplands of Wales. *(2004) Report Organic Centre Wales, Abersytwyth*

Gardner S M, et al.,A comparative review of the effects of organic farming upon biodiversity. *(1998)*

Report No OFO 149 ADAS Consulting

Griffiths G J K, Winder L, Holland J M , Thomas C F G , Williams E: The representation and functional composition of carabid and staphylinid beetles in different field boundary types at a farm scale. *(2007) Biological Conservation 135: 145 -152*

Hole, Perkins, Wilson, Alexander, Grice and Evans: Does organic farming benefit biodiversity? *(2005)*
Biological Conservation 122: 113 - 130

Holzschuh A, Steffan-Dewenter I, Kleijn D, Tscharntke T: Diversity of flower visiting bees in cereal fields: effects on the farming system, landscape composition and regional context. *(2007) Journal of Applied Ecology 44: 41- 49*

Hutton SA, Giller PS : The effects of the intensification of agriculture on northern temperate Dung Beetle communities. *(2003) Journal of Applied Ecology 40: 994 - 1007*

Keatinge R: Organic production in the hills and uplands. *(2005) Report no OFO 319 ADAS Consulting Ltd*
Redesdale.

Kragten S, de Snoo G R: Nest: success of Lapwings (*Vanellus vanellus*) on organic land and conventional arable farms in the Netherlands. *(2007) Ibis 149: 742 -749*

Langer V, The potential of leys and short rotation coppice hedges as reservoirs for parasitoids of cereal aphids in organic agriculture. *(2001) Agriculture, Ecosystems and Environment 87: 81 -92*

Ogilvy et al., Research into practice and policy: arable protection in the balance – profit and the environment. *Proceedings of a Home Grown Cereals Authority Conference(2006) London*

Pfiffner L, Merkelbach L, Henryk L : Do sown wildflower strips enhance the parasitism of lepidopteran pests in cabbage crops? *(2003) International Organisation for Biological and Integrated Control of Noxious Animals and Plants. West Palaearctic Regional Sectional Bulletin 26: 111-116*

Pfiffner L et al., Improvement of agricultural land to increase natural enemies in annual crops. (2003) Research Institute for Organic Agriculture (FiBL)

Phillips L et al., Do farm management practises alter soil biodiversity and ecosystem function?
Paper presented to Joint Organic Congress, Odense, Denmark, 2006.

Pommeresche R, Spiders in an organically managed ley pasture *(2004) Nowegian Journal of Entomology 49*

Purtauf T, Roschewitz I, Dauber J, Thies C, Tsharntke T, Wolters V : Landscape context of organic and conventional farms: influence upon carabid beetle diversity. *(2005) Agriculture, Ecosystems and the Environment 108: 165-174*

Rahmann G, Contribution of organic farming to conservation and improving biodiversity in Germany. *(2006) Colloquium of Organic Researchers Aspects of Applied Biology 79*

Ramert B et al., The use of mixed species cropping to manage pests and diseases. *Organic Research Conference Aberystwyth, March 2002*

Roschewitz I D, Gabriel T, Tscharntke C, Thies C: The effects of landscape complexity on arable weed species diversity in organic and conventional farming. *(2005) Journal of Applied Ecology 42: 873-882*

Rundlof M, Smith HGF: The effect of organic farming on butterfly diversity depends upon landscape context. *Journal of Applied Ecology (2006) 43: 1121 -1127*

Stoate C, Whitfield M, Szezur J, Williams P, and Driver K: Multifunctional benefits of an agri-environmental scheme option: Riparian buffer strip pools within Arable reversion. *(2007) Aspects of Applied Biology 81: 221 – 226*

Stoate C & Moorcroft D: Research based conversion at farm scale- development and assessment of Agri-Environmental Scheme -options. *(2007) Aspects of Applied Biology 81: 161 – 168*

Wickmansinghe L P, Harris S, Jones G, Vaughan N: Bat activity and species richness on organic and conventional farms; impact of agricultural intensification. *(2003) Journal of Applied Ecology 40: 948 – 993*

Wickmansinghe L P, Harris S, Jones G, Vaughan N, Jennings N: Abundance and species richness of nocturnal insects on organic and conventional farms: effects of agricultural intensification on bat foraging. *(2004)*