Rationale:

Traditional farming created some of the most diverse habitats in Europe. Over the last century economic and technological developments have drastically transformed European agricultural landscapes[1]. Intensification involved use of artificial fertilizers, improved crops and pesticides; modification of the landscape and specialization of farms[2]. This resulted in habitat and species loss, soil erosion, pollution and climate change[3] and in the last few decades we have seen huge declines in many farmland species[4].

The UK introduced agri-environment schemes (AES) in 1987 to counteract the negative effects of modern agriculture and many European countries now have AES[5] as a result of the EEC Regulation 2078/92. AES stimulate farmers to take measures that protect the environment by providing compensation and incentive payments. In England, the main AES are Environmentally Sensitive Areas (ESA) and the Countryside Stewardship Scheme (CSS), with similar schemes in the rest of the UK. These are mostly oriented to biodiversity conservation but also address landscape, historical and access objectives[6]. In common with several other countries, the UK AES reduce farming intensity by decreasing agrochemical usage, restricting livestock densities, constraining the timing of certain activities, requiring hedge maintenance and encouraging habitat creation.

Although evidence suggests AES can have a positive economic[7] and biodiversity[8] impacts there is much debate about the performance of AES in two areas, farmer uptake and effects on biodiversity. Assuming management prescriptions are appropriate, uptake becomes key to successful AES[9]. In early studies it was assumed that sufficient levels of uptake and removal of barriers to entry was a indicator of scheme success[9]. However, it has become clear that there are different levels of engagement with scheme aims, with limited engagement on the part of most participants[10] and the majority enticed into participation by payment rates and 'ease of fit' with existing farming system[11]. Such participants may fail to understand the reasoning behind prescriptions, leading to unintentional breaches. Indeed, some researchers have argued that "the possible shift towards conservation-oriented attitudes … should be seen as an important indicator of the effectiveness of [AES]"[10]. One way of doing this is by "educational programmes to push farmers from utilitarian ways of thinking towards conservation-oriented attitudes"[10]. It is also argued that training should involve understanding why certain actions are required as well as how to undertake conservation management[12]. We know little about how this cultural shift can be affected.

A recent review of biodiversity impacts of AES in Europe only found unequivocal evidence for positive effects on arthropods in 65% of studies, on plants in 43% and on birds in 21%[5]. In the UK AES have been shown to be successful at maintaining biodiverse habitats, but poor at rehabilitating degraded sites[13,14]. Thus, AES are not as good as they could be at increasing biodiversity[15]. The limited engagement of farmers is probably important, through inappropriate management[13]. A second, ecological, aspect is 'landscape context'. Even if a farmer creates appropriate habitats, success may be constrained by poor species colonisation. Small or distant source populations or dispersal barriers reduce colonisation rates by plants[16], butterflies[17] and birds[18]. Management can help by increasing dispersal, making landscapes more permeable, or targeting areas with good species pools[19]. However, there is little work on overcoming constraints generically for the range of dispersal and life history types of the species targeted by AES.

Specific objectives:

Improvement of AES must address social and ecological constraints in an integrated fashion. We will do this through the following objectives.

1) Explore farmer attitudes and approaches to agricultural management under AES.
2) Determine whether farmer attitude affects the biodiversity outcomes of AES.
3) Assess whether training of farmers can change attitudes towards AES and improve biodiversity outcomes.
4) Quantify the extent to which depauperate species pools and dispersal limitation constrain development of biodiversity under AES.
5) Develop strategies to overcome limitations imposed by species pools and dispersal, involving modified management at the landscape scale.
6) Determine whether improved environmental success of AES is a factor in altering farmer attitudes.
7) Model social and ecological constraints on success of AES and determine strategies to overcome them.

Methodology and approach:

Approach: We will compare farms in three categories: farmers without an AES contract, those in an AES and those in an AES who have undertaken additional training. We will study the impact of training on attitudes and knowledge of AES management and the process by which attitudinal shifts occur. We will determine how AES management, farmer attitude and training affect biodiversity change. Colonisation of farms by target species will be related to landscape context and farm habitat quality. Models will be developed for scenario testing of the extent to which farmer training and landscape management could enhance the biodiversity outcomes of AES.

This will be done in two areas representing the dominant environmental zones in lowland Britain, the arable east and the pastoral west. Within each landscape type we will identify eight farms in each of the three categories.

1) Arable cereal. These farms will be in the intensively managed landscape of eastern-central lowland England. Training will be through the Conservation Grade Farming Initiative established in 1989 (revised in 2003) to develop the concept of “farming for wildlife”. Participants are trained in agri-environmental policy and management of wildlife habitats. Each farm is required to manage 10% of the farmed area as wildlife habitat by, restricting pesticides, habitat creation and sympathetic management of boundary features. Training is funded under the Vocational Training Scheme (VTS), and management under the AES. There are 66 farms signed up to Conservation Grade.

2) *Pastoral*. We will use farms in the Grassland Challenge initiative. This brings the latest farming information and research findings to grassland farmers in South-West England using farmers' focus groups and focus farms. Subgroups of the farms are enrolled in AES which encourage appropriate management, creation of species-rich grassland, extensive management of field margins and restoration of boundary features. The VTS provides funds

for training in environmental land management. Since Grassland Challenge began in 2003 over 120 farms have signed up.

Methods:

Module 1: Project management. This module will coordinate activities for all other modules, ensuring methodological consistency, timely completion of tasks, effective networking between researchers and dissemination of project findings.

Module 2: Farmer attitude and responses to training. (Objectives 1, 3, 6). Semi-structured interviews with each of the 48 farmers will gather information on the farm, enterprise structure, social networks, educational and training history and attitudes towards AES. Observation and group discussions will examine the conduct and impact of training sessions. A sub-sample of farmers will be ‘shadowed’ to explore attitudes towards agri-environmental features on the farm and approaches to environmental management and to discuss changes resulting from training. Farmers will be re-visited in year 4 to determine the impact of participation and training on attitude towards and understanding of agri-environmental management and consider how information on the environmental outcome of AES may affect farmer attitude.

Module 3: Effects of AES and farmer attitude and training on habitat quality. (Objectives 2, 3). Measures of habitat quality in agricultural systems have been derived for a range of insects and birds using: the amount of non-crop habitat; plant diversity and vegetation structure; density of boundary hedges; and the abundance of nectar sources[20-24]. These will be used to develop habitat quality indicators which will be measured along transects at each farm in years 1 and 4. The relationships between habitat quality change and implementation of AES, farmer training, farmer attitude and management activities will be analysed using generalised linear models.

Module 4: Effects of landscape context on species colonisation. (Objectives 4, 5). Habitat quality does not necessarily predict the presence of target species[20] because colonisation may be limited. For example, occurrence of Dartford warbler in a heathland landscape was only predicted well when we included variables describing habitat isolation and barriers[25]. We will develop this approach with yearly surveys of the distribution of target species on each farm. These species are widespread, but declining in agricultural landscapes and represent different habitat needs and dispersal abilities. Examples include: skylark, meadow brown butterfly, *Bombus hortorum* (bumblebee), and *Rhinanthus minor* (plant). In years 1 and 4 surveys of these species will be done in the landscape around each farm, to a radius of 1 km**.** Landscape structure will be assessed using high resolution aerial photographs and surveys. Structure comprises the location and connectivity among features and can be summarised in simple indices[25,26]. The effects of farm habitat quality, landscape structure and species’ distribution on colonisation will be analysed by generalised linear models.

Module 5: Synthesis and Outputs. (Objective 7). We will partition the variance in biodiversity change in the study farms between ‘landscape factors’ (i.e. out of the control of the farmer) and ‘management factors’ (affected by attitude, etc.). Rule-based models will be constructed for scenario-testing of the consequences of modifying different factors. These will allow us to select strategies for success – should schemes be targeted to areas with appropriate landscape context or focus on training? We will also provide tools for measuring success of agreements. Outcomes will be explored through a series of farmer and stakeholder workshops which will consider receptiveness to, and the impact of, farmer training, and how to improve training. Outputs will include a series of ‘market tested’ training and targeting scenarios illustrating trade-offs between more rigorous training and targeting and stakeholder acceptability. Results will be published in internationally refereed journals and popular articles and presented at international conferences.

Programme of research

Activity	Year 1		Year 2		Year 3		Year 4		Year 5	
Site selection	■									
Module 1	■	■	■	■	■	■	■	■	■	■
Module 2	■	■	■	■			■	■		
Module 3	■	■	■				■	■		
Module 4		■	■	■	■	■	■	■		
Module 5								■	■	■

Justification for resources and project management:
The project will run for five years to allow sufficient time for habitat change and species colonisation. Work effort will be loaded to the start and end of the project, with fieldwork ending in year 4 and analysis, workshops and modelling happening in year 5. Staffing commitments (Section H) reflect intensive fieldwork needed for modules 2-4, involving farm visits for interviews and ecological surveys, and analysis and modelling in year 5. Institutional staff commitments reflect Investigator responsibilities: JMB for the whole project and Modules 1 and 5; ML for Module 2; RP for arable survey work in Modules 3 and 4; JT and SM for pastoral surveys. Staff at each institution will meet weekly and the Investigators will meet every 3 months.

Training: Staff will receive training in ecology, social science, statistical analysis, and modelling. A major element will be two-way education in ecology and social science for both staff and Investigators.

Data stewardship: Data will be maintained in common formats. After publications datasets will be stored at the Data Centre at CEH Monks Wood.

1. Donald et al. (2001). *Proc. Roy. Soc.* 268, 25. **2.** Giampetro et al. (1999). *Crit. Rev. Plant Sci.* 18, 261. **3.** Stoate et al. (2001). *J. Environ. Manage.* 63, 337. **4.** Benton et al. (2002). *J. Appl. Ecol.* 39, 673. **5.** Kleijn, Sutherland. (2003). *J. Appl. Ecol.* 40, 947. **6.** Ovenden et al. (1998). *J. Appl. Ecol.* 35, 955. **7.** Harrison-Mayfield et al. (1998). *J. Agric. Econ.* 49, 157. **8.** Carey (2001). *Nature* 414, 687. **9.** Whitby. (1994). *Incentives for countryside management*

(CABI). **10.** Wilson, Hart. (2001). *Sociologia Ruralis* 41, 254. **11.** Lobely, Potter. (1998). *Geoforum* 29, 413. **12.** Falconer. (2000). *J. Rural Studies* 16, 379. **13.** Critchley et al. (2004). *Biol. Conserv.* 115, 263. **14.** Carey et al. (2002). *Biol. Conserv.* 108, 183. **15**. Kleijn et al. (2001). *Nature* 413, 723. **16.** Bullock et al. (2002). in *Dispersal ecology* (Bullock et al.) (Blackwell). **17.** Chardon et al. (2003). *Landscape Ecology* 18, 561. **18.** Peach et al. (2001). *Biol. Conserv.* 101, 361. **19.** Bullock et al. (2002). *Dispersal ecology* (Blackwell). **20.** Petit et al. (2003). *Ecography* 26, 626. **21.** Petit et al. (2003). *Agric. Ecosyst. Environ.* 95, 19. **22.** Pywell et al. (2004). *Biol. Conserv.* 118, 313. **23.** Peach et al. (2004). *J. Appl. Ecol.* 41, 275. **24.** Westphal et al. (2003). *Ecol. Lett.* 6, 961. **25.** vandenBerg et al. (2001). *Biol. Conserv.* 101, 217. **26.** Vos et al. (2001). *Am.Nat.* 157, 24.