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Standard FEC Report

Scheme: Standard grant
Type: PI on a single grant

Award Holding Organisation

Organisation	University of Bristol	Research Organisation Reference:	BISC RA0420
Division or Department	Biological Sciences		

Title of Research Project

Biodiversity on farms: a complex systems approach

Project Details

Start Date	01/08/2006	Duration of Grant (months)	42
End Date	31/01/2010		
Report Due Date	01/05/2010		

Funds Awarded

Description	Full Economic Cost	BBSRC Contribution	Percentage Contribution by BBSRC
Total Grant Value	£ 915,746.30	£ 732,597.08	80 %

Investigators

Role	Name	Organisation	Division or Department	Hours/Week
Principal Investigator	Professor J Memmott	University of Bristol	Biological Sciences	5

Objectives

The main objectives of the research in order of priority [up to 4000 chars] at proposal time

OBJECTIVE 1: To construct a farm-scale quantitative network, of high species richness and taxonomic diversity, which contains indicator groups such as granivorous birds, arable plants and butterflies, along with the parasitoids, pollinators and seed dispersers which provide key ecosystem services, as well as pest species and the farmer.

OBJECTIVE 2: To model the extinction dynamics of the system by simulating primary species loss in the web and measuring the network's robustness in terms of the number and extent of secondary extinctions that follow. Different types of extinction will be modelled: a random removal (the null model) and systematic removals, each of the latter representing known threats to biodiversity. Having the farmer in the network will allow us to ask how she affects network structure and resilience.

OBJECTIVE 3: To test the following predictions: 1) taxonomically and trophically remote species interact directly and indirectly via a network of interactions that links species to each other; 2) plant and insect species form the bedrock of biodiversity in agro-ecosystems and the loss of these species will lead to a cascade of secondary extinctions that includes birds and mammals; 3) the rate of species loss depends upon whether the species that form the primary extinctions are specialists, generalists, of high trophic rank, wide ranging, rare or habitat-specific species.

OBJECTIVE 4: The degraded webs generated in Objectives 2 and 3 will be used to simulate the farm's restoration using the new Environmental Stewardship schemes. We will determine which combination of points provides the optimum return on payments from DEFRA. Specifically, we will test the hypotheses that within Environmental Stewardship, different management options will lead to different restoration outcomes, and that a given points target may have very different biodiversity outcomes depending on the selected permutation of management options.

Key milestones will include completion of [months from start of project in square brackets]: GIS mapping of the farm [1]; field sampling for the invertebrate networks [24]; field sampling for the vertebrate networks [24]; food web construction [26]; completing the complex systems programming [26]; running the extinction algorithms and testing the stewardship options [30]. Submission of papers to scientific and farming literature, food web displayed at Norwood farm [36]. A more detailed map of the timetable and tasks can be found in the Gantt chart (pg 11, case for support).

The main objectives of the research in order of priority [up to 4000 chars] at report time

N/A

Publication Summary

	Refereed Journal	Conference Proceedings	Books	Popular Journal	Other
Total	3	0	0	0	0
Total with Industrial Co-Authors	0	0	0	0	0
Total with International Co-Authors	0	0	0	0	0

Publications

Type	Title	Author(s)	Reference			
			Name	Year	Vol.	Page
Refereed Journal	The efficiency of a vacuum device in estimating soil-surface seed abundance on lowland farms	Dr Darren Evans Mr John MCloud Ms Lauren Pascoe Professor Jane Memmott	Weed Research	2009	49	337-40
Refereed Journal	The impact of farm management on the species-specific leaf area index (LAI): farm-scale data and predictive models	Dr Michael Pocock Dr Darren Evans Professor Jane Memmott	Agriculture, Ecosystems and Environment	2010	135	279-287
Refereed Journal	Pterandrophysalis levantina (Hymentopera: Trichogrammidae) a genus and species new to Britain and France	Ms Joanne Brooks Dr John McIvor Dr Andrew Polazek	The British Journal for Entomology and Natural History	2009	22	43-46

Results and Outputs

Resources generated.
Provide details of any new products or processes that were developed, e.g. reagents, cell lines, transgenic lines, software, analytical tools or methodology.

No resources were generated. New methods are being developed for analyzing food webs host to three ecosystem services.

Animal research addressing the 3Rs):
i) welfare
Describe any outcomes from the research that are relevant to animal welfare that are not covered in the full report.

N/A

Animal research addressing the 3Rs:
ii) reduction and replacement
Describe methods that were developed to reduce and replace animal experiments: the development of new alternative methods to animal models including in vitro methods, computational methods, non-animal methods and non-invasive in vivo methods.

N/A

Other results and outputs.

These are presented in full in the project report (see attachment), in summary they are as follows

1) Three scientific papers already published. One of the main data papers is submitted and out to review and three more are in preparation.

2) Extensive outreach programme run at field site and in Bristol.

3) The three staff are all employed following the end of this grant (a Conservation Biology lectureship, a NERC Fellowship and job in University Administration)

Results Exploitation and Knowledge Transfer

Data/sequences lodged in public access databases. Give details of database(s).

Data will be placed in the ecological network interaction database held at NCEAS, California when the project data is fully analysed. This is the standard method of making ecological network data available to scientific community/general public.

Licenses and/or patents. Give full details.

N/A

Spin-out company. Give details of incorporation date, turnover, staff numbers, etc.

N/A

Industrial collaborations. Include grants from, or formal collaborations with, industry or elsewhere, or exchanges of staff, materials or results.

N/A

Science in Society

Describe activities undertaken to enhance public engagement with the biosciences by the PI, component grant holder, PhD student or employee funded during the course of the grant. Activities can cover broader areas than your grant and could include media interactions and media training, public meetings and lectures, exhibitions, open days, school events, etc. Presentations at scientific conferences or articles in refereed journals do not count as public engagement.

The PDRA's working on the project (Evans & Pocock) have been actively involved in 'citizen science' projects with the public and schoolchildren. In 2008 they were awarded an RCUK National Science and Engineering Week grant to talk about ecological networks using 'alien' leafminers (i.e. one of the function groups included in this project) with the public at Bristol's largest shopping centre, and the 'Norwood Farm Project' was showcased (see www.ourweboflife.org.uk). Approximately 2000 members of the public learned about food webs and took part in a real citizen science experiment. In 2009 they received further funding from NERC and BES to investigate, with 900 schoolchildren, the importance of parasitoids in ecological network. Publicity for this was achieved through local newspapers, radio and TV interviews, with

excellent feedback from participants (reports are available on request).

Throughout the project, posters and photos were displaced in the tearoom/farm shop at the field site as a very effective means of communicating to the public. The PDRA's gave a number of talks to schoolgroups visiting the farm. Norwood is an open farm with c. 10,000 members, as well as casual visitors and shoppers, and consequently our posters have a large readership of visitors and school-children. Feedback on the research from the public and the staff running the tearoom was excellent.

A Café Scientifique talk was given by Memmott to the General Public in Bristol on biodiversity on farms and, specifically, the work done in this research project.

"Meet a Moth" events were run in eight Bristol primary schools (an article was published on event this in BBSRC Business). These were run by Memmott in collaboration with the Avon Wildlife Trust and involved taking the contents of a moth trap into school (c. 500 live moths). Each child got to see and hold a live moth and discussions followed regarding insect natural history, the importance of the environment and biodiversity on farms.

A "Meet a bumblebee nest" event was trialled by Memmott in two classes at a local school. A commercially available live bumblebee colony was taken into school (sealed shut!) and 60 children got to see the bees and their nest up close. The importance of bees in pollination was discussed.

Summary

The research described in lay terms, that could be publicised to a general audience [up to 4000 chars]

Original Summary

BACKGROUND: The intensification of arable agriculture over the last 50 yrs has been associated with substantial losses of biodiversity and there is considerable concern that intensive agriculture is incompatible with the conservation of biodiversity. Moreover, there is disquiet that studying indicator groups such as farmland birds is not providing the information needed to foster biodiversity. Our aim is to construct a large ecological network for an organic farm showing how species are linked to each other and then to use a complex systems approach to predict the impact of species loss and species restoration.

WHY STUDY THIS SUBJECT AREA? If ecologists, land managers and policy makers are to manage farmland biodiversity sustainably, then they need to understand the ways in which species are linked to each other. Complex systems theory predicts that that the extinction of just a few highly-linked species could lead to a cascade of secondary extinctions, which could cause a complete collapse of the web. Put simply, complex systems such as a farm food web can be very vulnerable to rather small disasters.

THE PROPOSAL: We will construct a farm-scale network, which contains plants, insects, birds and mammals as well as insect pest species and the farmer. Once we have constructed the web, which we expect will link about 1000 species to each other in a single network, we will model the impact of species extinction. We will do this by using a computer to simulate primary species loss in the web (by removing species one by one from the network) and measuring the network's robustness in terms of the number and extent of secondary extinctions that follow. A remarkably small number of primary extinctions can cause a trophic cascade. For example, the simulation of a 10% species loss in a 154 species network was sufficient to elicit a cascade of secondary extinctions which led to network collapse. Having the farmer in our network will allow us to ask how she affects network structure and resilience. Finally, the degraded webs generated by the computer will be used to model the farm's restoration using DEFRA's new agri-environment scheme, Environmental Stewardship. We will be able to discover the best way to reinstate the network of interactions between the species that make up the farm's biodiversity. Although they are designed to increase farmland biodiversity, very little testing of the environmental impact of agri-environment schemes takes place. Given that £2.7 billion is spent annually on such schemes in the European Union, tools for assessing the efficacy of agri-environment schemes are badly need.

WHY IS THIS SUBJECT EXCITING, INTERESTING AND IMPORTANT? Food webs and other ecological networks have not yet been widely applied to the field of sustainable agriculture. Given the practical advances being made in network construction (for example, in eco-informatics), the theoretical advances (for example, complex systems approaches) and the ongoing threat of biodiversity loss combined with ambitious agri-environment schemes, now is a very exciting time to begin to use ecological networks as a practical tool for managing biodiversity on the 77% of our land occupied by farmland.

WHAT ARE THE WIDER BENEFITS TO SOCIETY? Understanding the ecology of managed landscapes is fundamental for achieving more sustainable agriculture and for the conservation of biodiversity on farmland. The healthy functioning of natural and managed habitats provides free "ecosystem services" essential to mankind. These include, for example, pollination, pest control and water filtration. The delivery of these ecosystem services is dependent on biodiversity, and consequently the services, and very probably mankind, could be threatened by further reductions in biodiversity.

Revised Summary

UPDATED SUMMARY

Understanding the ecology of managed landscapes is fundamental for achieving a more sustainable agriculture and for the conservation of biodiversity on farmland. The healthy functioning of natural and managed habitats provides free "ecosystem services" essential to mankind. These include, for example, pollination of crops, insect pest control and plant seed dispersal. The delivery of these ecosystem services is dependent on biodiversity. The intensification of arable agriculture over the last 50 yrs has been associated with substantial losses of biodiversity and there is considerable concern that intensive agriculture is incompatible with the conservation of biodiversity. Moreover, there is disquiet that studying indicator groups such as farmland birds is not providing the information needed to foster biodiversity, and the ecosystem services it provides, more generally. Our aim here was to construct a large ecological network for an organic farm showing the complex ways in which whole communities of species are linked to each other and then to predict the impact of species loss and species restoration on the provision of three ecosystem services: pest control, pollination and seed dispersal. While previous projects have considered ecosystem services individually, this project is the first to consider several simultaneously. This is important as they are not independent, for example, without pollination there will be no seed dispersal network.

THE PROJECT AND KEY RESULTS: We chose a well-established organic farm as our field site and intensive sampling took place over the first two years of the project. The underlying rationale of the sampling was to express the abundance of all species (from foxes to flies) in common units, here the number of individuals per hectare. The key results are as follows:

1) Plant and insect species form the bedrock of biodiversity in agro-ecosystems. In our network, 93% of the 876 species sampled were plants and insects and the loss of these species will lead to a cascade of secondary extinctions that includes birds and mammals.

2) Taxonomically and trophically remote species interact directly and indirectly via a network of interactions that links species to each other. The three ecosystem services are inextricably intertwined and should not be considered in isolation.

3) A small proportion of plant species have a disproportionately beneficial effect on biodiversity, abundance and biomass at higher trophic levels. For example, the top 5 plant taxa were responsible for 40% of the richness of species interactions of pest controllers and pollinators.

4) These plants should be the focus of restoration efforts, and specifically considered within agri-environment schemes, because they will disproportionately increase the abundance and biomass of organisms that can be fed on by species at higher trophic levels, e.g. birds and mammals.

5) The three ecosystem services differ significantly in how they react to species loss. Pollination is more resistant to species loss than pest control, which is more robust than seed dispersal.

SUMMARY: Food webs and other ecological networks have not yet been widely applied to the field of sustainable agriculture. Three-quarters of the UK is used for farmland where most biodiversity is found. We demonstrated that simple management decisions by farmers can dramatically affect the abundance and composition of plant primary producers (Pocock et al. 2010), leading to significant cascading effects throughout the network and on ecosystem services (Evans et al. submitted). Given the magnitude of these effects on farmland biodiversity, targeted management decisions at the farm scale and based on the whole community will be crucial for halting biodiversity loss. We have shown that ecological networks can be a practical tool for restoring and managing biodiversity, and the ecosystem system services it provides.

Technical Summary

at proposal time

Most data on declines in farmland biodiversity are clustered around particular indicator groups such as farmland birds, arable weeds or butterflies, describing for example their species richness or abundance. There is increasing disquiet however, since this type of data may not provide the information needed for a wildlife-compatible agriculture, particularly when wanting to conserve ecosystem services, as these depend on interactions between species. Here, we will construct a farm-scale network of interactions, which contains indicator groups such as the granivorous birds, arable plants and butterflies, along with the parasitoids, pollinators and seed dispersers which provide key ecosystem services, as well as pest species and the farmer. Once the web is complete, our aim is to use a complex systems approach to simulate primary species loss in the web and measure robustness in terms of the secondary extinctions that follow. Different types of extinction will be modelled, a random removal (the null model) and systematic removals, each of the latter representing known threats to biodiversity. Having the farmer in the network will allow us to ask how she affects network structure and resilience. Specifically we will test the following predictions: 1) taxonomically and trophically remote species interact directly and indirectly via a network of interactions that links species to each other; 2) plant and insect species form the bedrock of biodiversity in agro-ecosystems and the loss of these species will lead to a cascade of secondary extinctions

that includes birds and mammals; 3) the rate of species loss from the network depends upon whether the species that form the primary extinctions are specialists, generalists, of high trophic rank, wide ranging, rare or habitat-specific species. The degraded webs generated by the complex systems analysis will be used to simulate the farm's restoration using DEFRA's new Environmental Stewardship schemes.

Staff

Role Name	Name / Post Identifier	Grade / Scale	Start Date	End Date	Hours / Week	Gender	Qualifications gained on project
Researcher	Dr Darren Evans	RA2A	04/09/2006	31/12/2009	37.5	Male	PDRA
Researcher	Dr Michael Pocock	RA1A	01/08/2006	31/01/2009	37.5	Male	PDRA
Researcher	Ms Joanna Brooks	RA1B	01/08/2006	31/05/2009	37.5	Female	Graduate Research Assistant

Staff Destinations

Name	Organisation details	Employment type
Dr Darren Evans	University of Hull Hull United Kingdom	HigherEducationResearch
Dr Michael Pocock	University of Bristol School of Biological Sciences United Kingdom	HigherEducationResearch
Ms Joanna Brooks	University of Bristol Faculty of Engineering United Kingdom	HigherEducationOther

FINAL REPORT QUESTIONAIRE

1) What were the most significant achievements from this grant? (up to three, no more than 150 words in total)

1) SCIENTIFIC EXCELLENCE: We believe that the work will lead to a paradigm shift in the way we look at biodiversity in agroecosystems from looking at the species richness of a few key groups (e.g. farmland birds) to looking at the conservation/restoration of ecosystem function.

2) IMPACT: The restoration and conservation of ecosystem function in agroecosystems can be jump-started by ensuring that key plant groups are present on the farm. Thus the top five plant taxa (n = 175) were responsible for 40% of species interactions in pest control and pollination.

3) TRAINING: All three members of staff have procured excellent jobs: Evans has a lectureship in Conservation Ecology at the University of Hull; Pocock has a NERC Fellowship at the University of Bristol and Brooks has a job in University Administration at University of Bristol. Moreover, four of our field assistants have gone on to study for PhDs in Ecology.

2) Indicate whether or not the main objectives of this grant were met, and for any which were not met, provide a brief explanation (no more than an average of 50 words for each, no more than 300 words in total).

The four objectives of the grant were all met, thus we:

1) Constructed a farm-scale quantitative network, of high species richness and taxonomic diversity, which contains indicator groups such as granivorous birds, arable plants and butterflies, along with the parasitoids, pollinators and seed dispersers which provide key ecosystem services, as well as pest species and the farmer (OBJECTIVE 1). There are 876 species in our network: 175 plants, 641 insects, 50 birds and 10 mammals.

2) We modelled the extinction dynamics of the system by simulating primary species loss in the web and measuring the network's robustness in terms of the number and extent of secondary extinctions that follow (OBJECTIVE 2) (e.g. Figure 1).

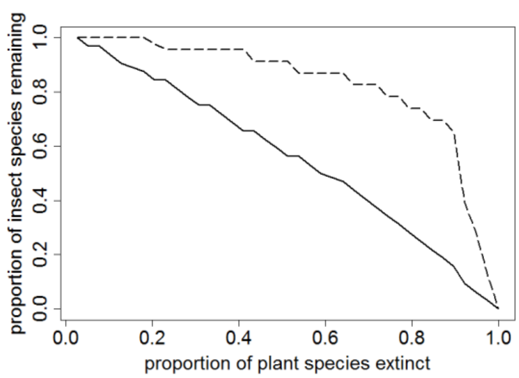

Figure 1: The cascading effects of the predicted loss of plant species is more immediate on lower trophic levels (here represented by aphids, solid line) than on higher trophic levels (here represented by aphid parasitoids, dotted line). In this example, the richness of biocontrol agents is predicted to the less sensitive than the richness of herbivores (potential pests) to the loss of plant richness.

3) We clearly demonstrated that taxonomically and trophically remote species interact directly and indirectly via a network of interactions that links species to each other (specifically through plants as a shared primary resource, with different insect groups using the leaves, flowers or

seeds as resources) and tested the prediction that plant and insect species form the bedrock of biodiversity in agro-ecosystems and the loss of these species will lead to a cascade of secondary extinctions. (OBJECTIVE 3) (e.g. Figure 2).

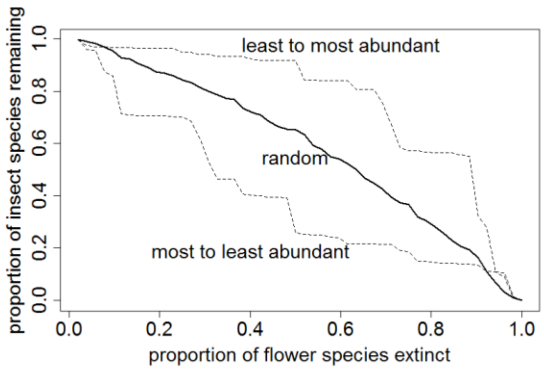

Figure 2: The order of the predicted extinctions has a dramatic effect on the loss of pollinator species. Here flower abundance was derived from field surveys on the farm. Clearly the loss of the most abundant species first has the greatest effect on pollinators. Notably the most abundant species are white clover and cereal weeds, the latter being most likely to be reduced with agricultural intensification. Steep parts of the curves indicate the loss of species that are particularly important (e.g. hawthorn, bramble and creeping thistle).

4) The web is currently being used to simulate the restoration of farmland biodiversity using the Environmental Stewardship schemes. We are testing which combination of points provides the optimum return on payments from DEFRA (OBJECTIVE 4). To date our results are contrary to general recommendations. Thus the traditional approaches for agri-environment schemes (and those preferred by land managers) focus on non-cropped areas (e.g. hedgerows and field margins), but we predict that small changes in infield conservation measures will have a much larger effect on the insect biodiversity, abundance and biomass available to species higher up the food chain, such as predatory insects, birds and bats.

Two methods papers have been published in preparation for the high impact data papers (Evans et al 2009, Pocock et al. 2010), along with a taxonomic paper describing a genus and species of parasitoid new to Britain and France reared from the field site (Polazek, McIvor & Brooks 2009). The first of the main data papers (Evans, Pocock, Brooks & Memmott) is currently out to review at the *Journal of Applied Ecology*; the others will be submitted over the remainder of 2010.