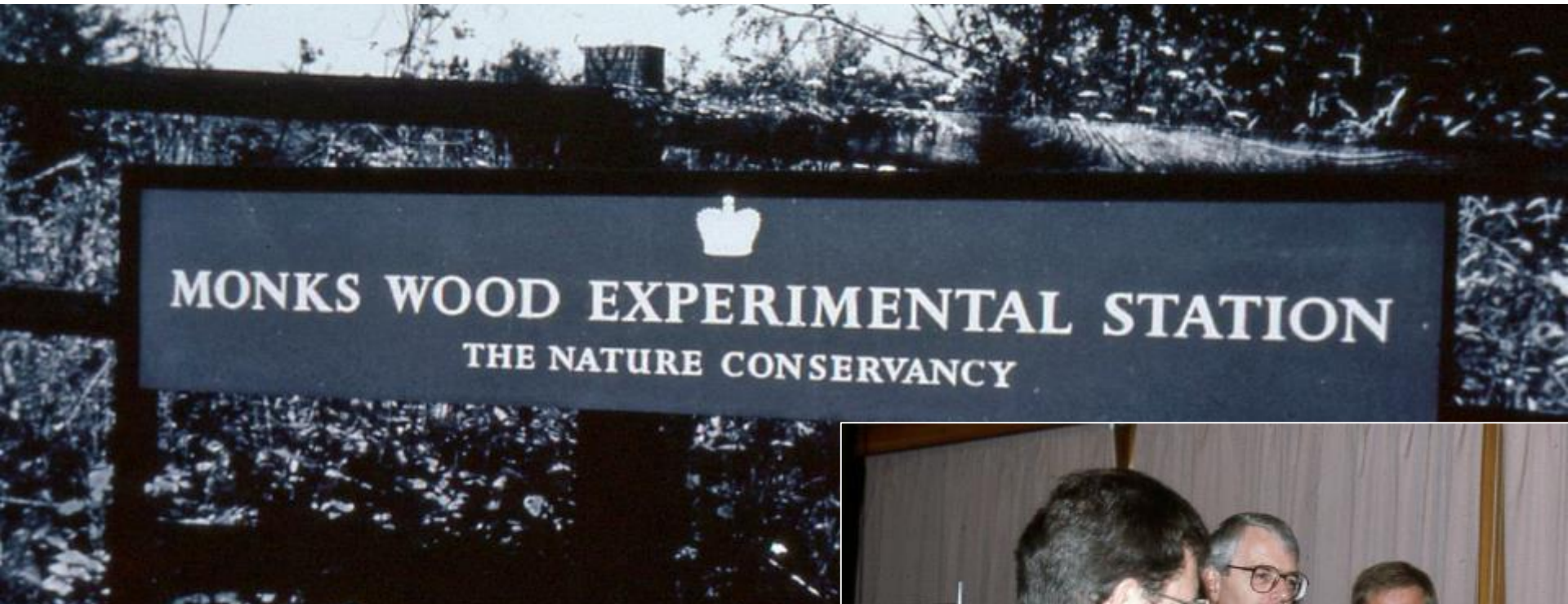




Species-rich Grassland Restoration: 45 Years of Research

Richard Pywell

1. The Terry Wells Legacy



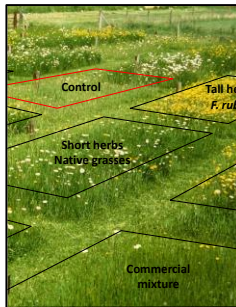
1. Compensate for loss of spp-rich grassland
2. Develop restoration techniques based on detailed research & knowledge of ecology
3. Translate this into practical applications with commercial appeal



45 Years of Research

.. 1973 1978 1980 1995 2003 2005+

**First
restoration
expt. at
Royston**



- Seed mix trials
- Slot-seeding
- Plug plants
- Hay bales



- Seed
production
- Commercial
seed houses
established



EMORSGATE SEEDS

- Attributes of
difficult
species
- Overcoming
biophysical
limitations



- Yellow rattle
as a tool for
restoration

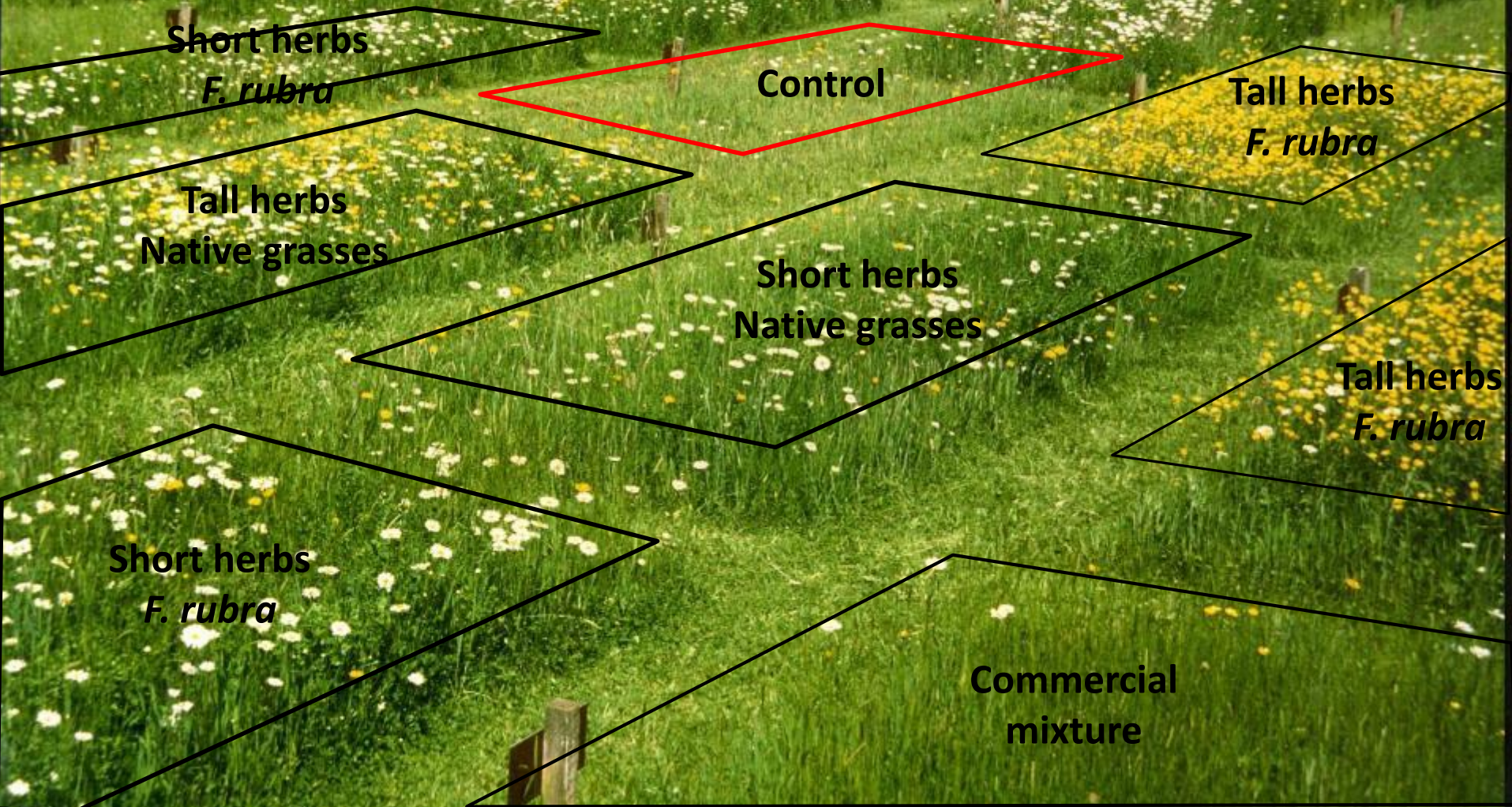


- Soci-
economic
perspectives
- Ecosystem
service
benefits



Seed Mixture Experiments

- Demonstrated it was possible!
- Seed rates & composition
- Native vs bred cultivars
- Nurse species



New restoration techniques for farmland & amenity areas



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Creating attractive grasslands using native plant species

Isary Wells, Staling Bell and Alan Price

NUMBER 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150 2160 2170 2180 2190 2200 2210 2220 2230 2240 2250 2260 2270 2280 2290 2300 2310 2320 2330 2340 2350 2360 2370 2380 2390 2400 2410 2420 2430 2440 2450 2460 2470 2480 2490 2500 2510 2520 2530 2540 2550 2560 2570 2580 2590 2600 2610 2620 2630 2640 2650 2660 2670 2680 2690 2700 2710 2720 2730 2740 2750 2760 2770 2780 2790 2800 2810 2820 2830 2840 2850 2860 2870 2880 2890 2900 2910 2920 2930 2940 2950 2960 2970 2980 2990 3000 3010 3020 3030 3040 3050 3060 3070 3080 3090 3100 3110 3120 3130 3140 3150 3160 3170 3180 3190 3200 3210 3220 3230 3240 3250 3260 3270 3280 3290 3300 3310 3320 3330 3340 3350 3360 3370 3380 3390 3400 3410 3420 3430 3440 3450 3460 3470 3480 3490 3500 3510 3520 3530 3540 3550 3560 3570 3580 3590 3600 3610 3620 3630 3640 3650 3660 3670 3680 3690 3700 3710 3720 3730 3740 3750 3760 3770 3780 3790 3800 3810 3820 3830 3840 3850 3860 3870 3880 3890 3900 3910 3920 3930 3940 3950 3960 3970 3980 3990 4000 4010 4020 4030 4040 4050 4060 4070 4080 4090 4100 4110 4120 4130 4140 4150 4160 4170 4180 4190 4200 4210 4220 4230 4240 4250 4260 4270 4280 4290 4300 4310 4320 4330 4340 4350 4360 4370 4380 4390 4400 4410 4420 4430 4440 4450 4460 4470 4480 4490 4500 4510 4520 4530 4540 4550 4560 4570 4580 4590 4600 4610 4620 4630 4640 4650 4660 4670 4680 4690 4700 4710 4720 4730 4740 4750 4760 4770 4780 4790 4800 4810 4820 4830 4840 4850 4860 4870 4880 4890 4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160 5170 5180 5190 5200 5210 5220 5230 5240 5250 5260 5270 5280 5290 5300 5310 5320 5330 5340 5350 5360 5370 5380 5390 5400 5410 5420 5430 5440 5450 5460 5470 5480 5490 5500 5510 5520 5530 5540 5550 5560 5570 5580 5590 5600 5610 5620 5630 5640 5650 5660 5670 5680 5690 5700 5710 5720 5730 5740 5750 5760 5770 5780 5790 5800 5810 5820 5830 5840 5850 5860 5870 5880 5890 5900 5910 5920 5930 5940 5950 5960 5970 5980 5990 6000 6010 6020 6030 6040 6050 6060 6070 6080 6090 6100 6110 6120 6130 6140 6150 6160 6170 6180 6190 6200 6210 6220 6230 6240 6250 6260 6270 6280 6290 6300 6310 6320 6330 6340 6350 6360 6370 6380 6390 6400 6410 6420 6430 6440 6450 6460 6470 6480 6490 6500 6510 6520 6530 6540 6550 6560 6570 6580 6590 6600 6610 6620 6630 6640 6650 6660 6670 6680 6690 6700 6710 6720 6730 6740 6750 6760 6770 6780 6790 6800 6810 6820 6830 6840 6850 6860 6870 6880 6890 6900 6910 6920 6930 6940 6950 6960 6970 6980 6990 7000 7010 7020 7030 7040 7050 7060 7070 7080 7090 7100 7110 7120 7130 7140 7150 7160 7170 7180 7190 7200 7210 7220 7230 7240 7250 7260 7270 7280 7290 7300 7310 7320 7330 7340 7350 7360 7370 7380 7390 7400 7410 7420 7430 7440 7450 7460 7470 7480 7490 7500 7510 7520 7530 7540 7550 7560 7570 7580 7590 7600 7610 7620 7630 7640 7650 7660 7670 7680 7690 7700 7710 7720 7730 7740 7750 7760 7770 7780 7790 7800 7810 7820 7830 7840 7850 7860 7870 7880 7890 7900 7910 7920 7930 7940 7950 7960 7970 7980 7990 8000 8010 8020 8030 8040 8050 8060 8070 8080 8090 8100 8110 8120 8130 8140 8150 8160 8170 8180 8190 8200 8210 8220 8230 8240 8250 8260 8270 8280 8290 8300 8310 8320 8330 8340 8350 8360 8370 8380 8390 8400 8410 8420 8430 8440 8450 8460 8470 8480 8490 8500 8510 8520 8530 8540 8550 8560 8570 8580 8590 8600 8610 8620 8630 8640 8650 8660 8670 8680 8690 8700 8710 8720 8730 8740 8750 8760 8770 8780 8790 8800 8810 8820 8830 8840 8850 8860 8870 8880 8890 8900 8910 8920 8930 8940 8950 8960 8970 8980 8990 9000 9010 9020 9030 9040 9050 9060 9070 9080 9090 9100 9110 9120 9130 9140 9150 9160 9170 9180 9190 9200 9210 9220 9230 9240 9250 9260 9270 9280 9290 9300 9310 9320 9330 9340 9350 9360 9370 9380 9390 9400 9410 9420 9430 9440 9450 9460 9470 9480 9490 9500 9510 9520 9530 9540 9550 9560 9570 9580 9590 9600 9610 9620 9630 9640 9650 9660 9670 9680 9690 9700 9710 9720 9730 9740 9750 9760 9770 9780 9790 9800 9810 9820 9830 9840 9850 9860 9870 9880 9890 9900 9910 9920 9930 9940 9950 9960 9970 9980 9990 10000



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Focus on nature conservation

No. 15

Wild flower grasslands
from crop-grown seed and hay-bales



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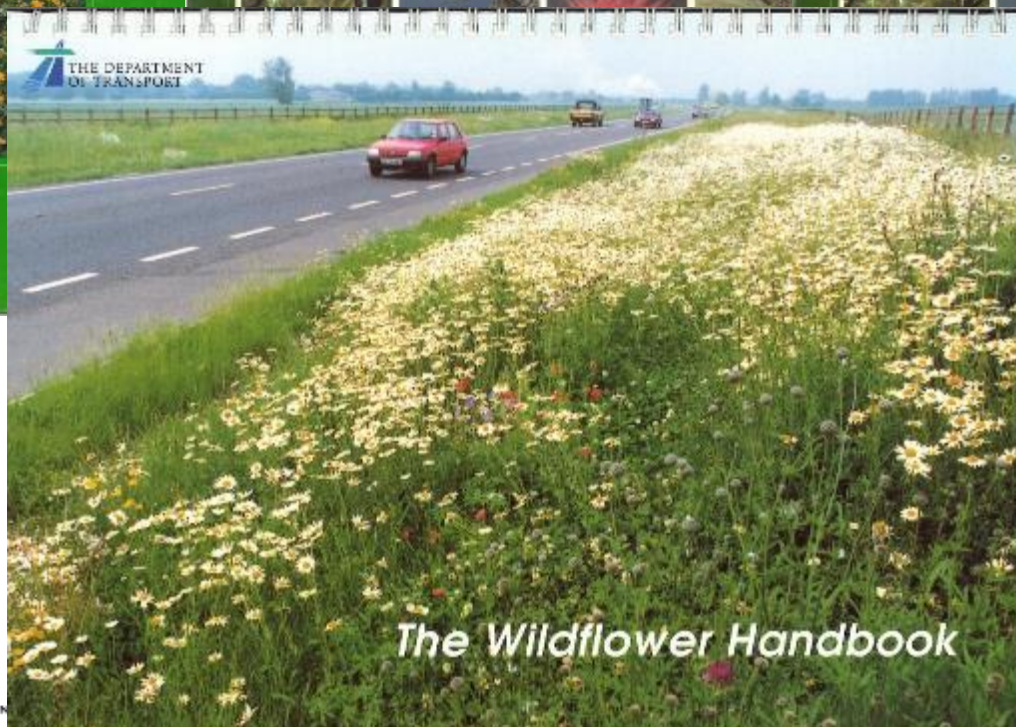
Focus on nature conservation

No. 21

The establishment and management
of wildflower meadows



ISSN 0254-6674



THE DEPARTMENT
OF TRANSPORT

The Wildflower Handbook

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NERC
SCIENCE OF THE
ENVIRONMENT



2. Characteristics of 'Easy' & 'Difficult' Wildflower Species

Attributes of easy & difficult species

- Meta-analysis of plant traits vs. performance in restoration
 - **32 arable reversion expts**
 - **18 grassland diversification expts**
 - **Duration between 2 and 30 years**
- Calculated expt-adjusted Performance Index
 - **14 grasses & 45 forbs**
- ANOVA / linear regression to relate performance to 38 plant traits and environmental associations

Results (Performance Index in Year 4)

Good

PI_4
1.2-0.8

*e.g...Festuca rubra, Trisetum flavesens, Cynosurus cristatus, Antoxanthum odoratum
Leucanthemum vulgare, Trifolium pratense,
Achillea millefolium, Lotus corniculatus*

Moderate

PI_4
0.8-0.3

e.g... Rumex acetosa, Prunella vulgaris, Centaurea nigra, Rhinanthus minor, Sanguisorba minor

Bad

PI_4
<0.3

*e.g...Thymus polytrichus, Succisa pratensis,
Sanguisorba officinalis, Helianthemum nummularium, Filipendula vulagris, Hippocrepis comosa, Stachyis officinalis*

Attributes of easy & difficult species

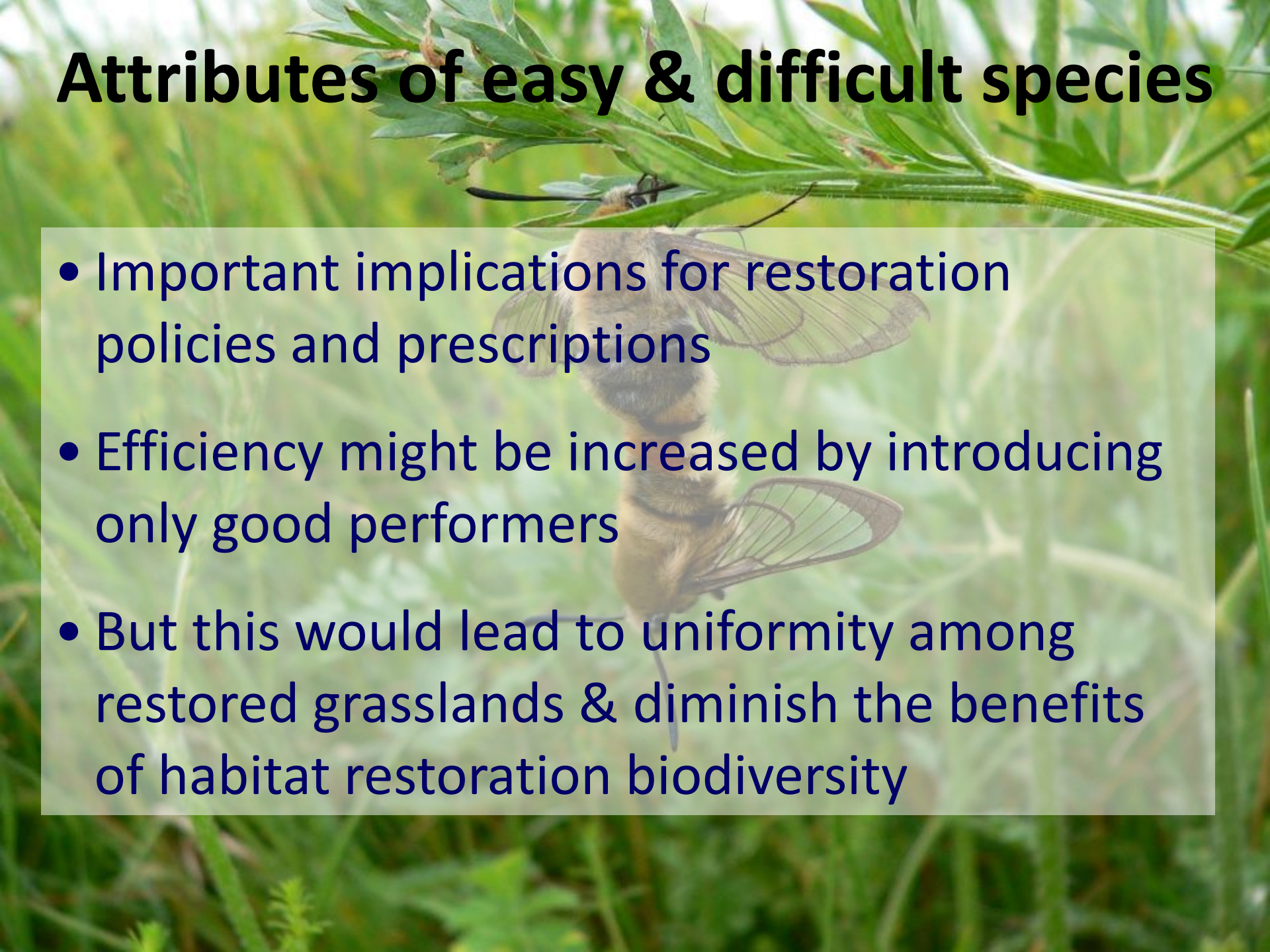


Good performers	Bad performers
- Wide amplitude (= Generalists!) - C-strategists (yr 1: R-strategists) - Adapted to high fertility - Persistent seed bank and / or vegetative spread	- Narrow amplitude (= Specialists!) - S-strategists - Adapted to low fertility - Dependent on seasonal regeneration from seed



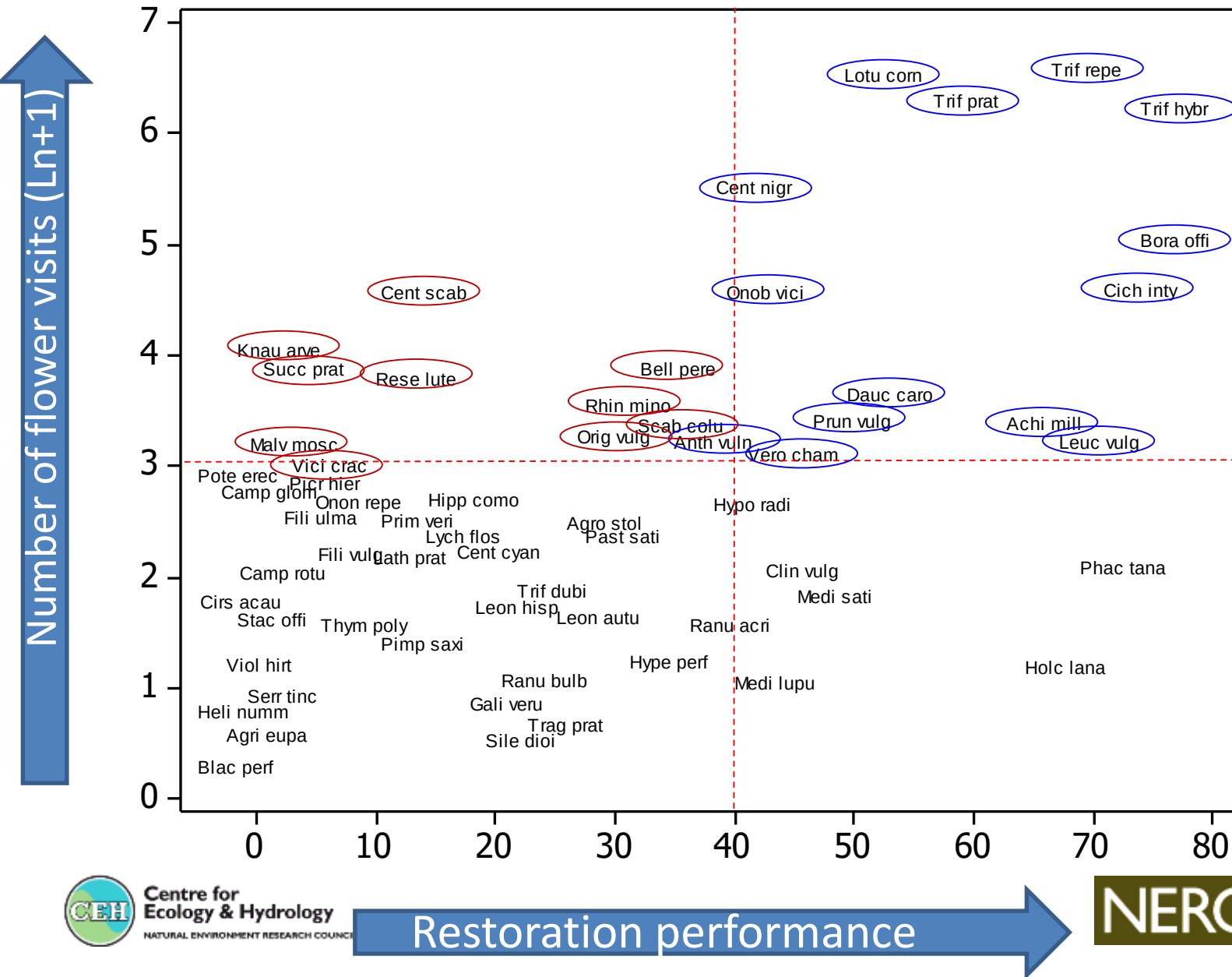
- Findings valid for BOTH initial establishment AND subsequent performance
⇒ Amplification of effects over time!

Attributes of easy & difficult species

A close-up photograph of a moth with brown and white wings perched on a green, leafy plant stem. The background is a soft-focus green field.

- Important implications for restoration policies and prescriptions
- Efficiency might be increased by introducing only good performers
- But this would lead to uniformity among restored grasslands & diminish the benefits of habitat restoration biodiversity

Use Case: Designing Pollinators Mixes



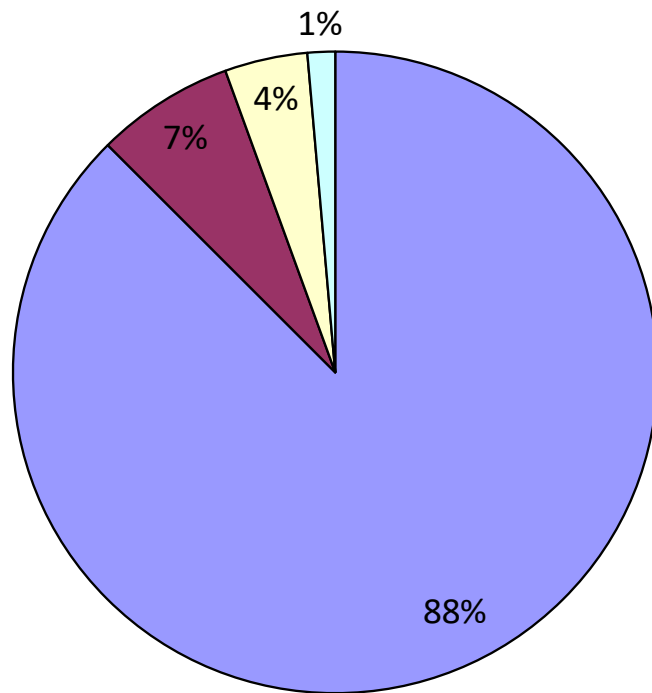


3. Overcoming Biophysical Constraints

Lack of seed desirable species

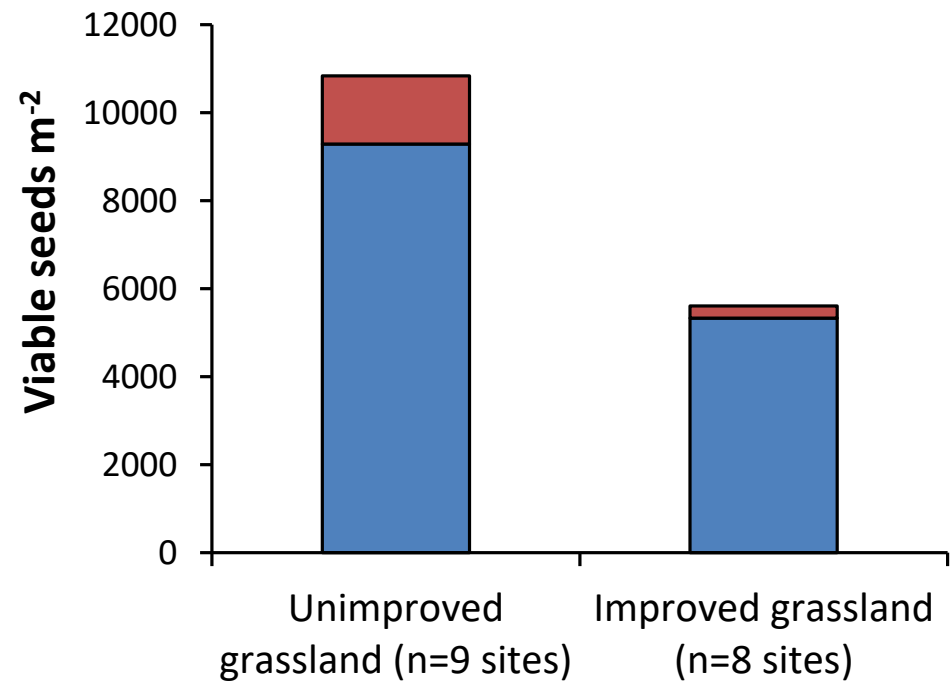
MG5: *Cynosurus cristatus*-*Centaurea nigra* meadow & pasture

a) Seed bank persistence



- Transient
- Short-term persistent
- Long-term persistent
- Not assigned

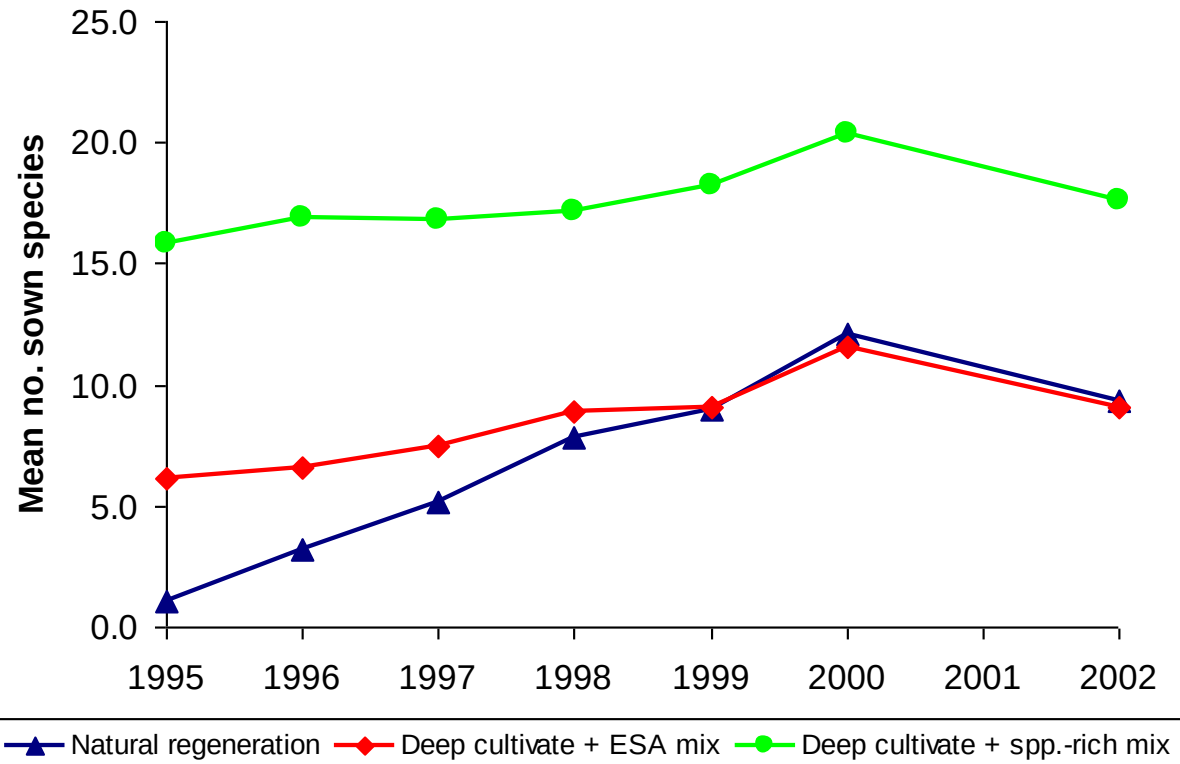
b) Seed bank size / composition



- Undesirable species
- Desirable species

Wagner, Walker & Pywell (2017)
Restoration Ecology

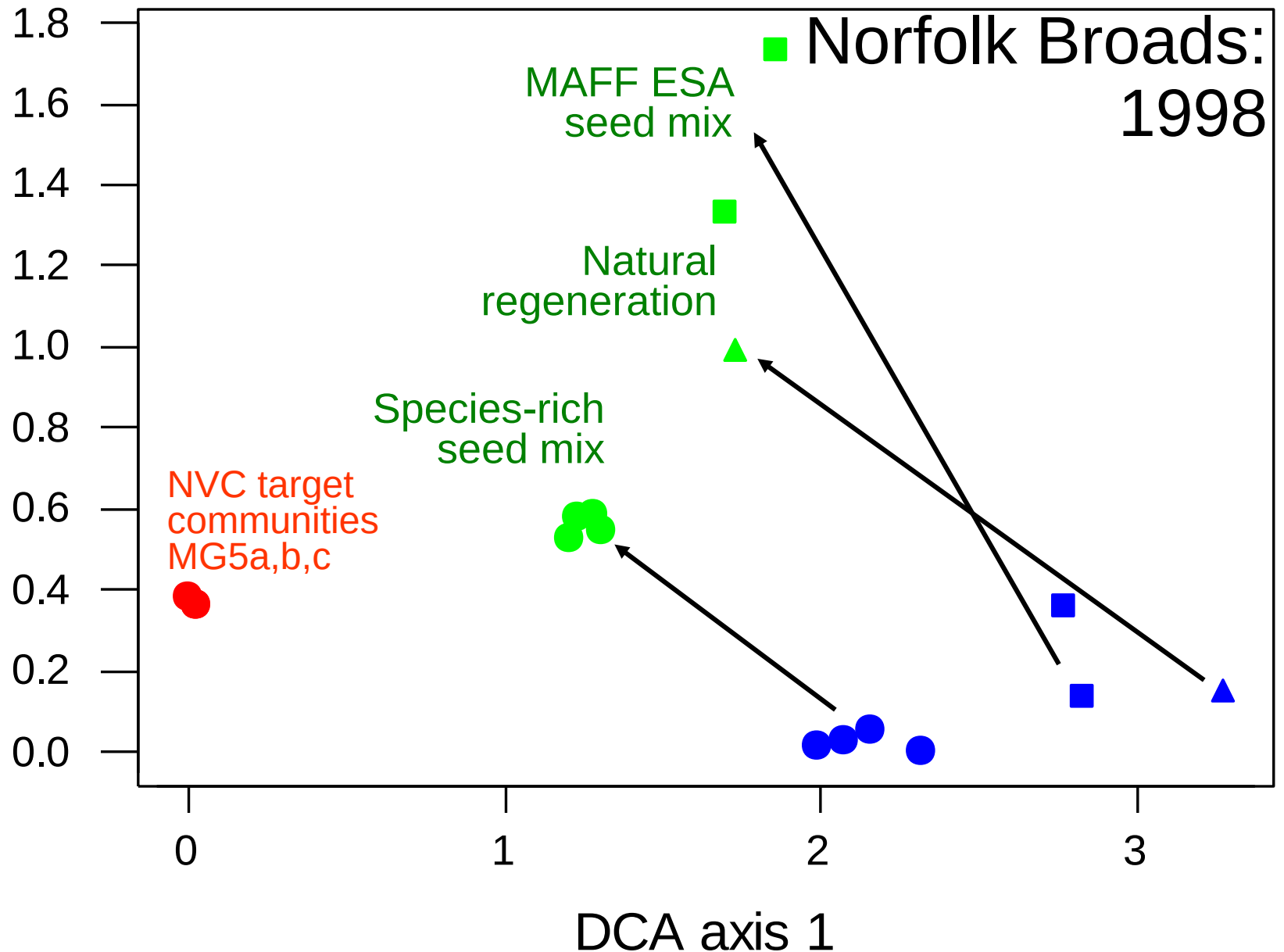
Effects of seed addition



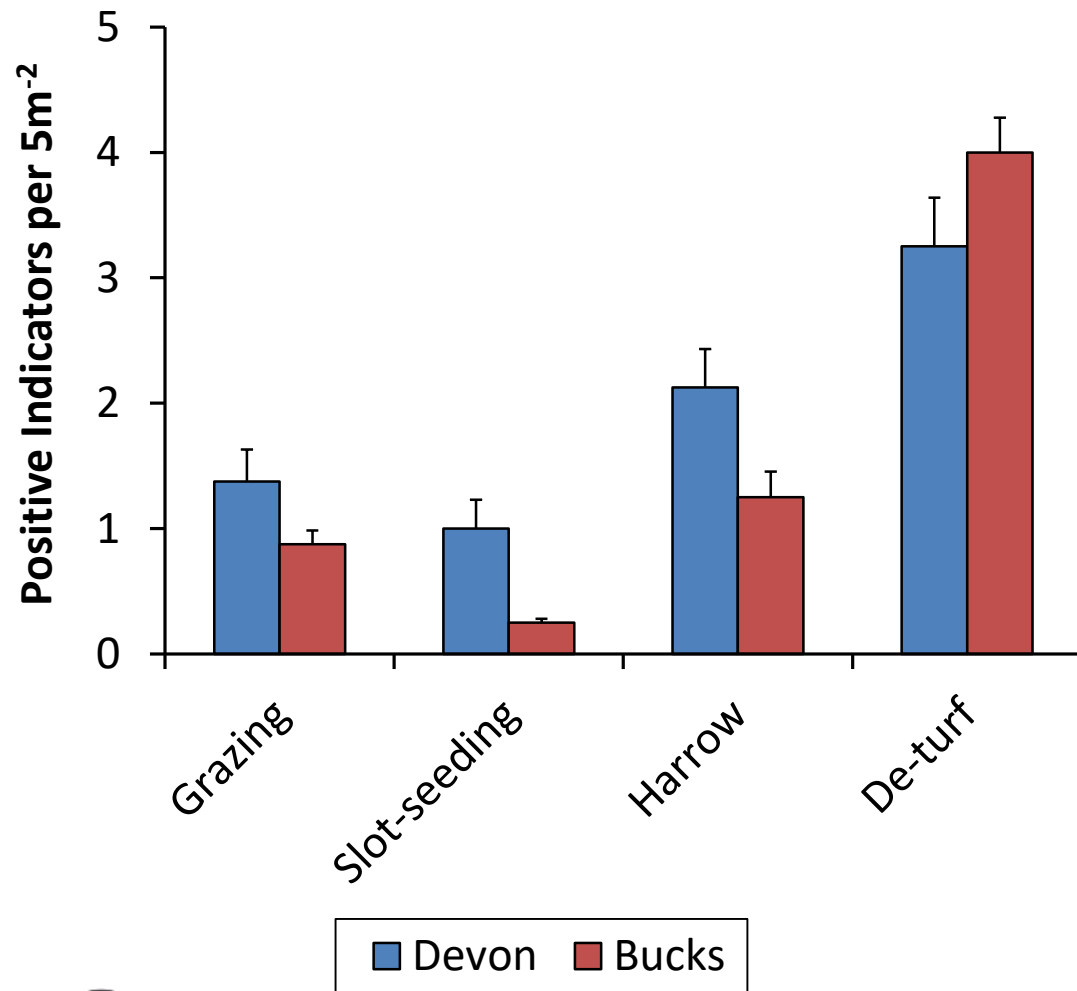
- Six sites over 8 years
- Effects of cultivation on fertility
- Nurse crops
- Seed mixes



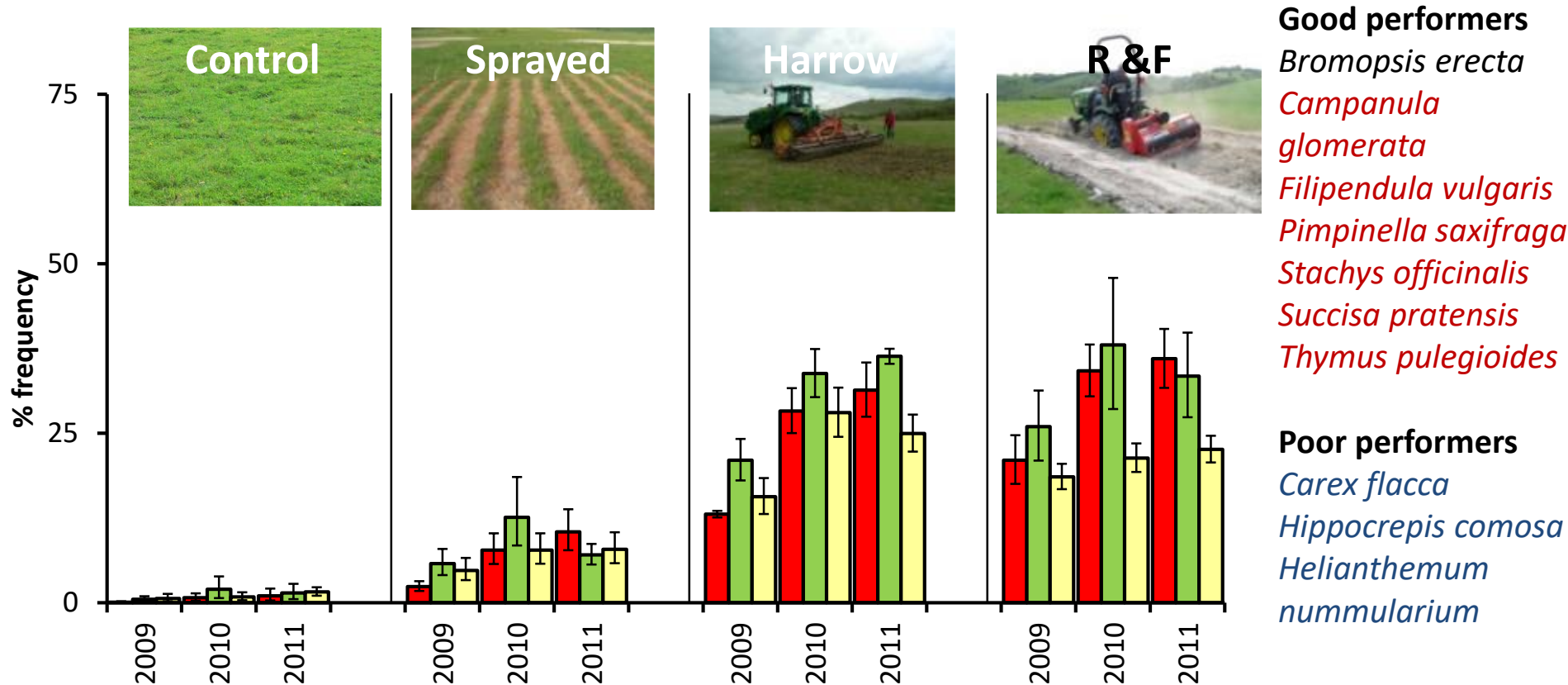
Similarity to Spp-rich Target Community



Effects of disturbance on establishment



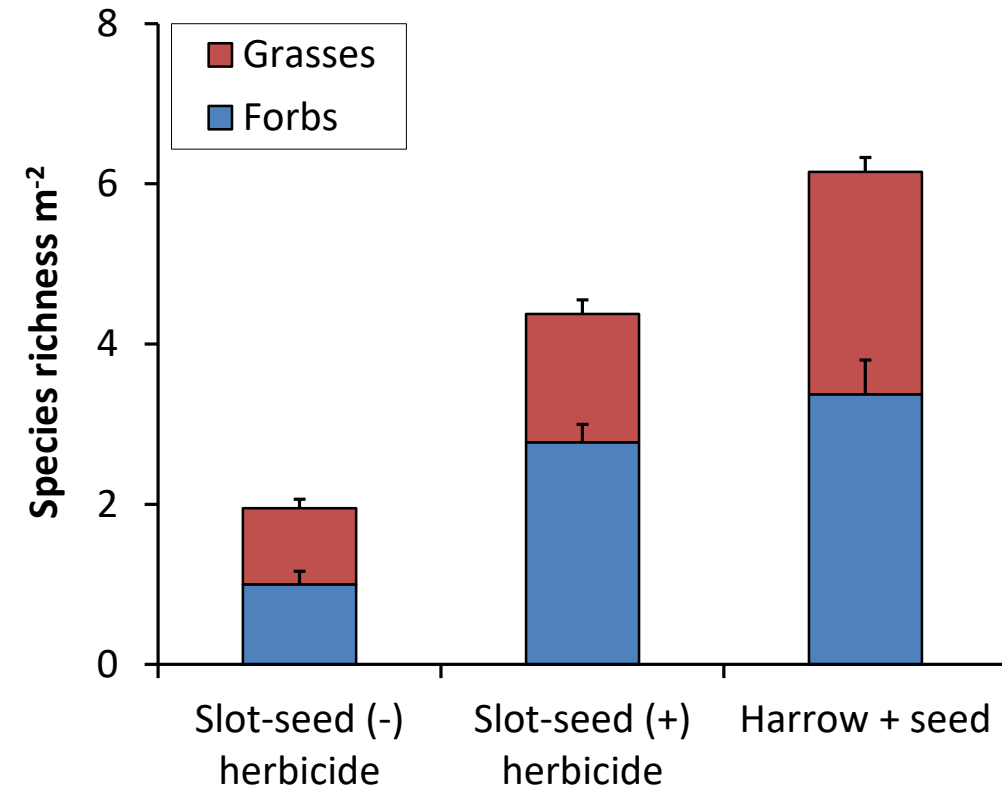
Severe (temporary) disturbance for restoration



- Sum cut / Aut cattle
- Spr sheep / Sum cut / Aut cattle
- Spr sheep / Sum cattle / Aut Cattle

Rep. Measures ANOVA	F-value (Sign.)
Grazing Regime _{2,9}	1.07 (ns)
Disturbance _{3,27}	146.15 (***)
Year _{2,18}	47.90 (***)
Grazing × Yr _{4,18}	2.66 (ns)
Disturbance × Yr _{6,54}	4.03 (*)
Grazing × Disturbance _{6,27}	1.15 (ns)
Grazing × Dist. × Yr _{12,54}	0.63 (ns)

Herbicides to Increase Establishment



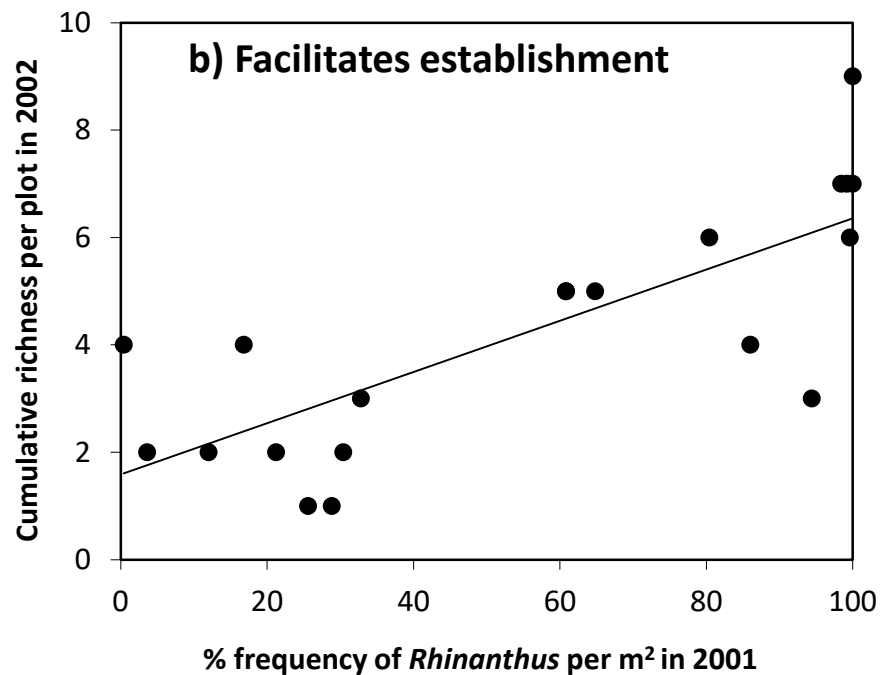
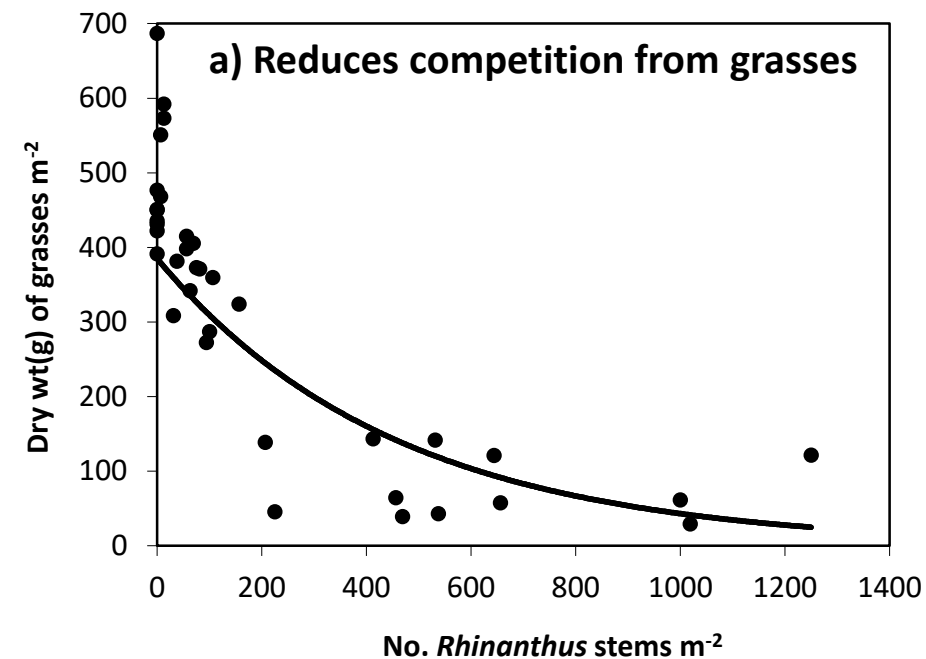
Slot-seeding = 3.3 kg ha⁻¹ / £115 ha⁻¹

Harrowing = 10.0 kg ha⁻¹ / £350 ha⁻¹



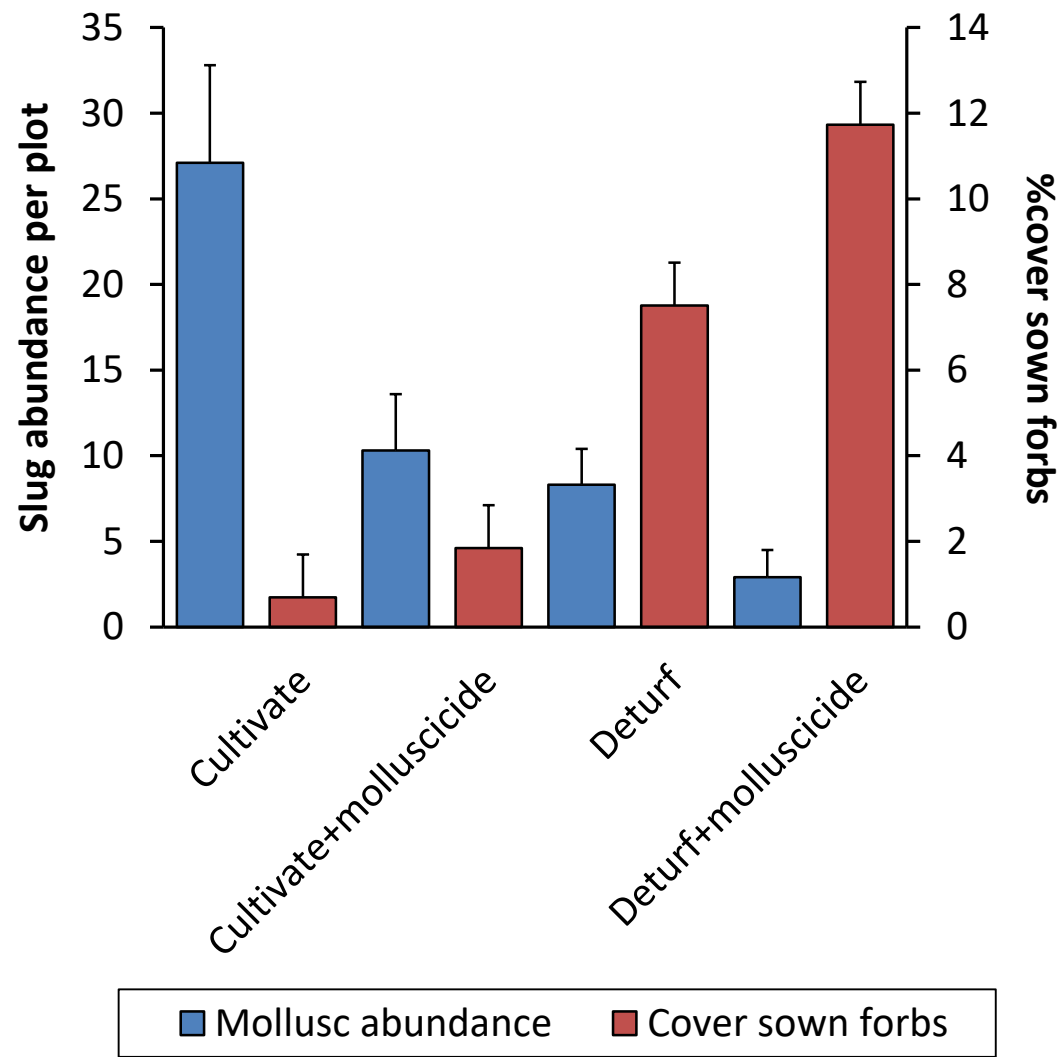
Using Yellow rattle as a tool to restore diverse grassland

1. Widespread species of many grasslands
2. Seed relatively cheap & easily obtainable
3. Easily established and spread
4. Reduces vigour of competitive species (esp. grasses)
5. Facilitates establishment & persistence of target species
6. Population size can be controlled by mowing



Frequency	Correlation <i>Rhinanthus</i>
<i>Achillea millefolium</i>	0.59**
<i>Centaurea nigra</i>	0.59**
<i>Hypochoeris radicata</i>	0.20nsd
<i>Leontodon autumnalis</i>	0.48*
<i>Leontodon hispidus</i>	0.37nsd
<i>Leucanthemum vulgare</i>	0.52*
<i>Lotus corniculatus</i>	0.15nsd
<i>Plantago lanceolata</i>	0.83***
<i>Prunella vulgaris</i>	0.49*
<i>Trifolium dubium</i>	0.56**

Controlling mollusc herbivory

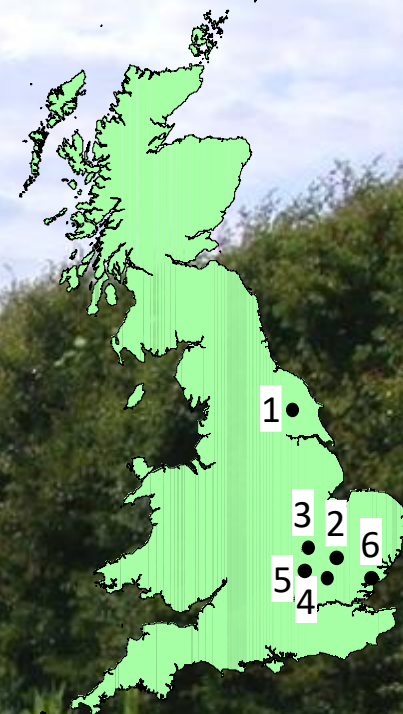




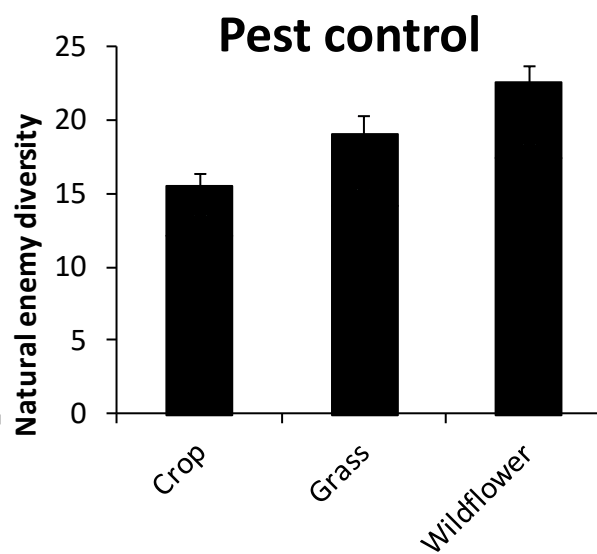
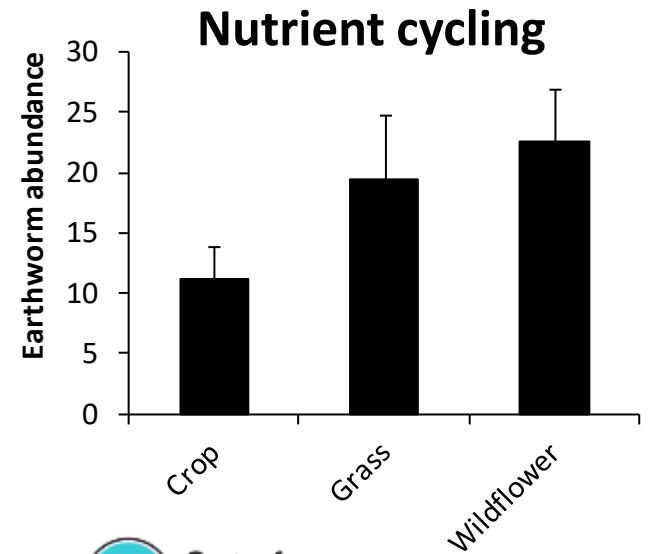
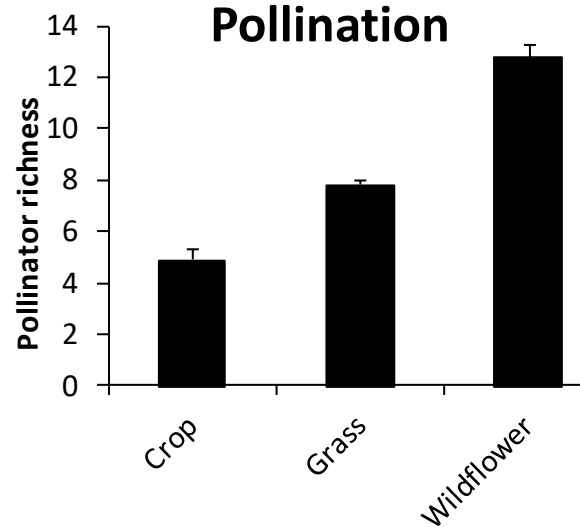
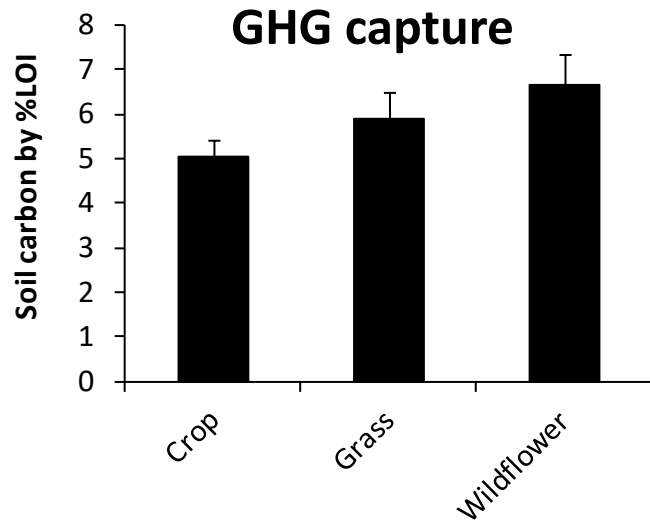
4. Ecosystem Service Benefits



- Six commercial farms
- Six new AES prescriptions tested
- Conventional crop control
- 5 years monitoring



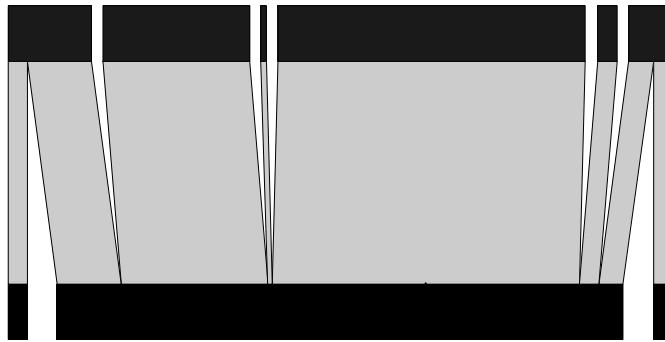
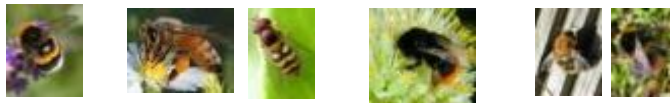
Multiple Benefits from Wildflower Margins



More resilient pollination service in restored grasslands?

Pollinator-plant interaction web

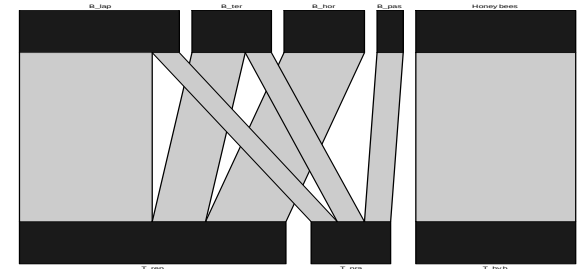
Pollinator species



Plant species

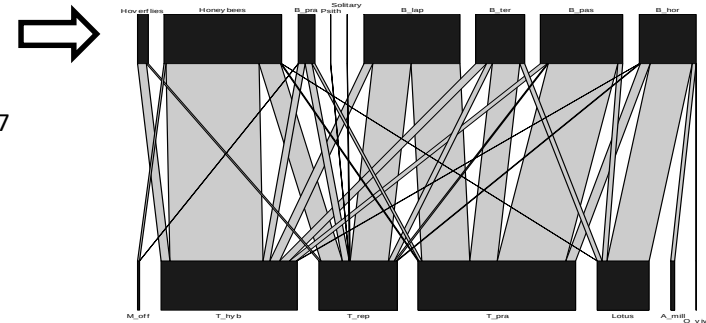
Grass only →

Linkage density=1.55



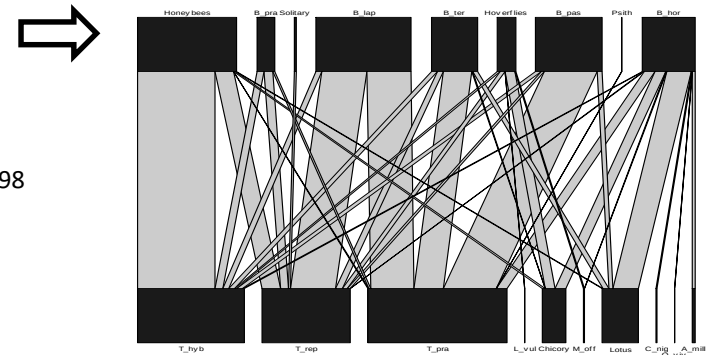
Grass & legumes →

Linkage density=2.77



Grass, legume & Forb →

Linkage density=2.98



Restoration of biodiversity increases ecosystem productivity

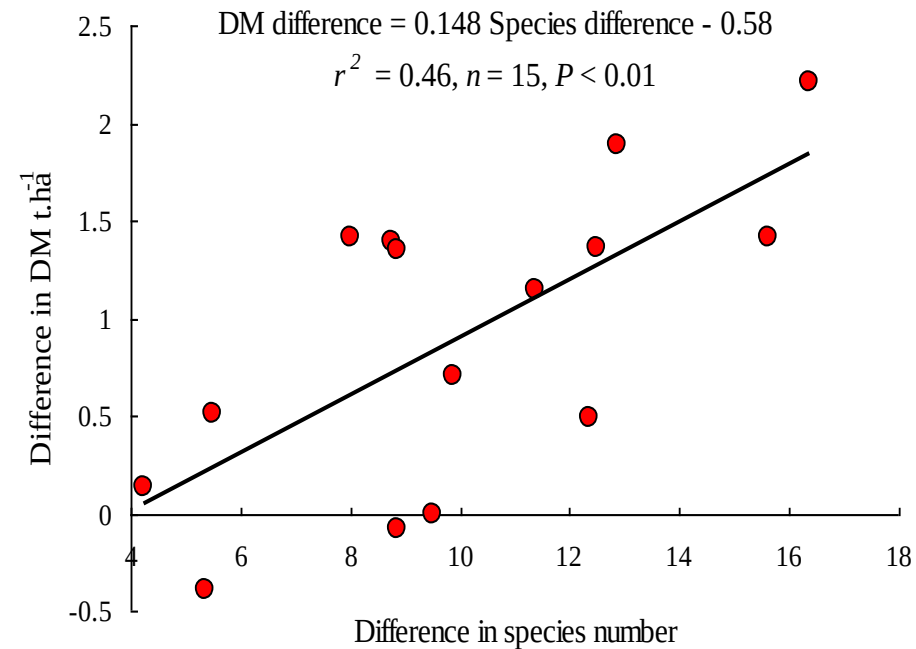
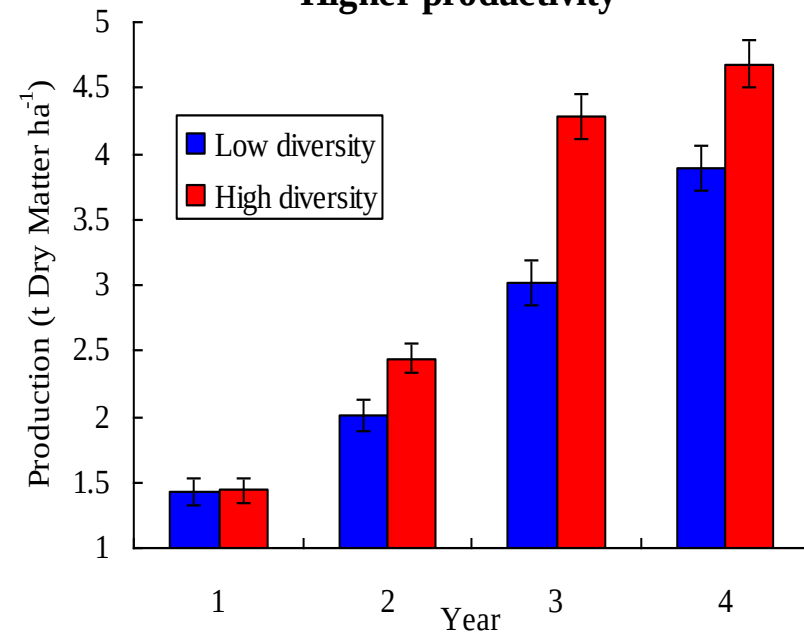
Standard seed mix (6-8 species)



Rich seed mix (25-41 species)



Higher productivity

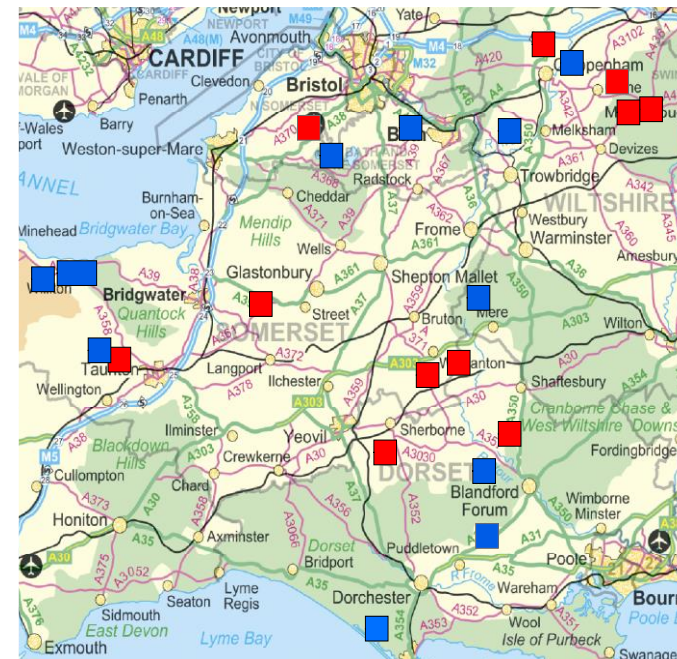
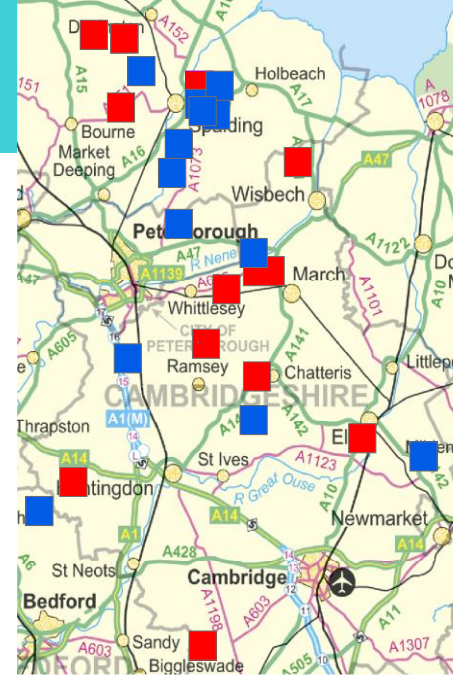




5. Socio-economic Barriers to Success: *The Importance of Training & Advice*

Socio-economic perspectives

- Two landscapes – SW & East
- In each 24 farms – 12 trained, 12 untrained
- Explore farmer attitudes to AES & responses to training
- Assess habitat quality of AES options
- Determine sociological & ecological success of AES over 5 years



50 YEARS WITH
IMPACT

Journal of Applied Ecology

Journal of Applied Ecology 2015

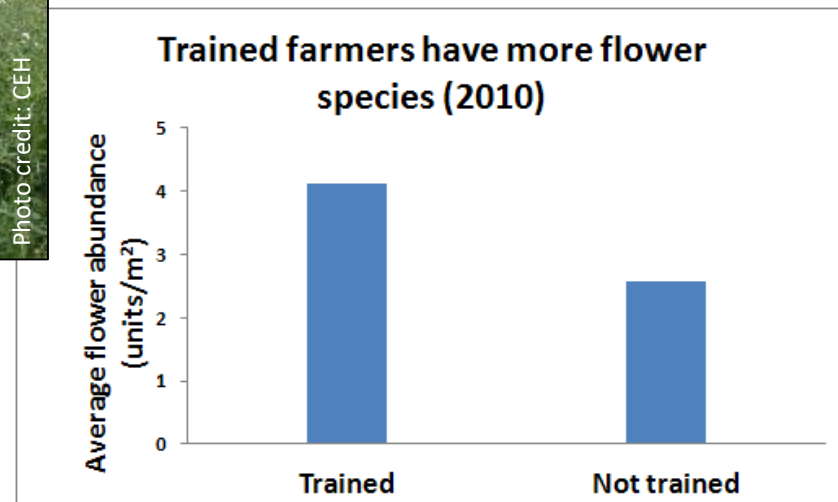
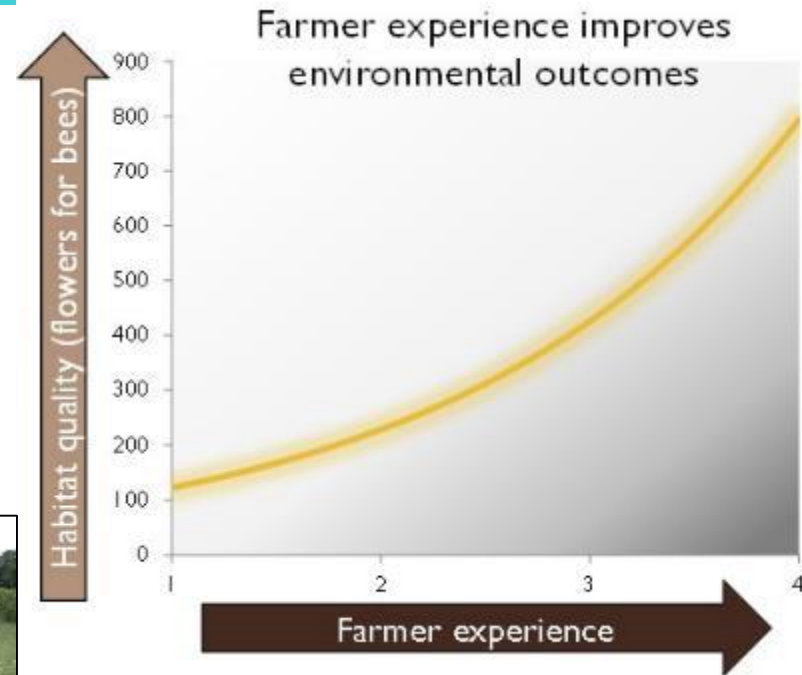
doi: 10.1111/1365-2664.12412

Social and ecological drivers of success in agri-environment schemes: the roles of farmers and environmental context

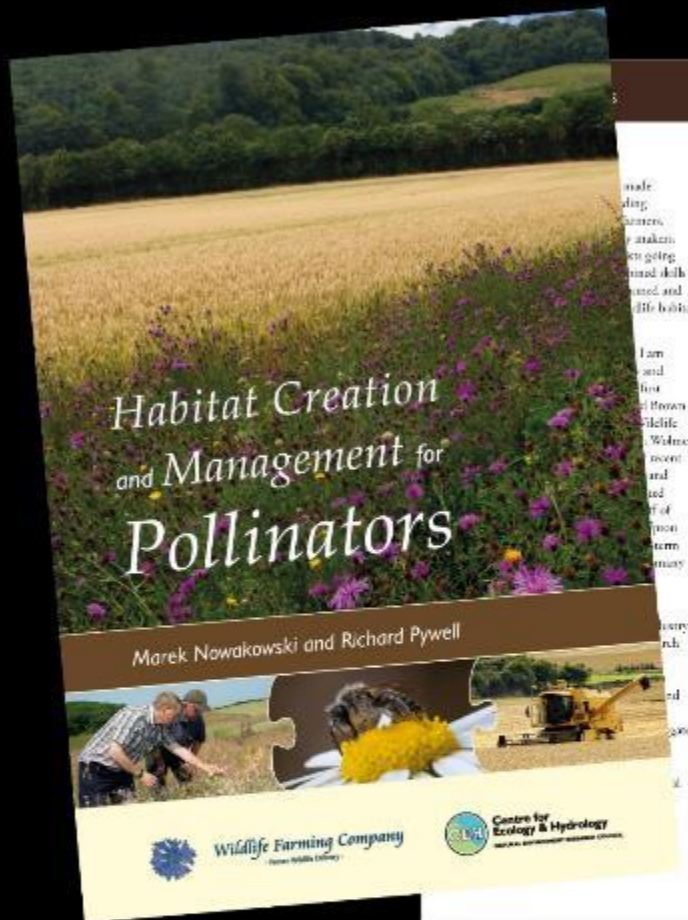
Morag E. McCracken¹, Ben A. Woodcock¹, Matt Lobley², Richard F. Pywell¹, Eirini Saratsi², Ruth D. Swetnam^{1,3}, Simon R. Mortimer⁴, Stephanie J. Harris⁴, Michael Winter², Shelley Hinsley¹ and James M. Bullock^{1*}

Farmer training delivers more pollinators

- Farmer experience of agri-environment & training had a strong +ve effect on quality of spp-rich grassland produced
- Bee abundance & diversity was much higher on these better quality, farmer managed habitats



Evidence-based, practical guidance



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sumers,
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hand skills
and and
life habitat

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England), Richard Brad Hardy (Defra),
Ken Storer and Bill Mole.

Special thanks to Mike Edwards for his
technical input and field visits relating
to bee ecology, and David Bellamy for
his continued encouragement - without
his inspiration this book would not have
been written.

Finally, thanks to Heather Llewellyn
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designing this book. The following
kindly gave their permission to use their
excellent images: Chris Stoddard, Marcus
Jenett, Rusey, Peter Brough, Bright
Scrubridges and Osmos Pro.

I have been lucky enough to be an
enthusiastic member of this team and
hope this book will provide insights into
the fascinating world of pollinators and
show how we can balance profitable
farming with practical conservation.

Marek Nowakowski
Wildlife Farming Company



Illustration courtesy of Peter Brough - www.bumblebee.co.uk

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Restored chalk grassland nr Aston Rowant

Conclusions

Conclusions

1. Key constraints are lack of seeds & establishment sites
2. Natural regeneration unlikely to provide acceptable outcomes
3. Seed or green hay addition highly effective at overcoming this
4. Severe (temporary) sward disturbance using cultivation or herbicide needed in permanent grassland
5. Management of biotic interactions can enhance effectiveness of restoration



Conclusions

6. Training land managers improves restoration success
7. Restoration enhances important ecosystem functions and services:
 - ***Herbage production/quality***
 - ***GHG capture***
 - ***Pollination***
 - ***Pest control***



Acknowledgements

- Our funders
- Terry Wells for his vision & knowledge of grassland ecology
- All the field assistants and site managers for maintaining the experiments and collecting the data

