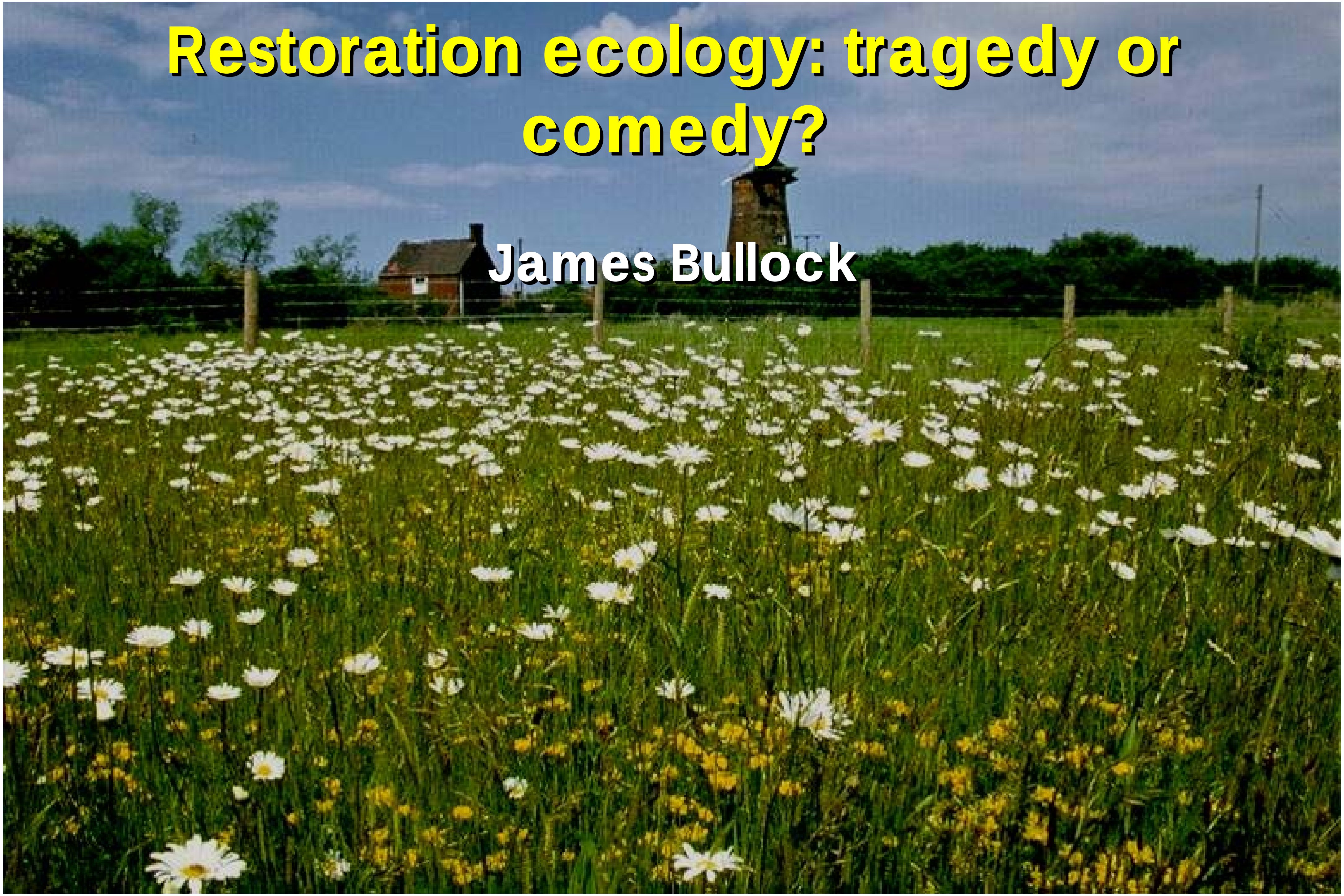

Restoration ecology: tragedy or comedy?
James Bullock

Biodiversity destruction & loss

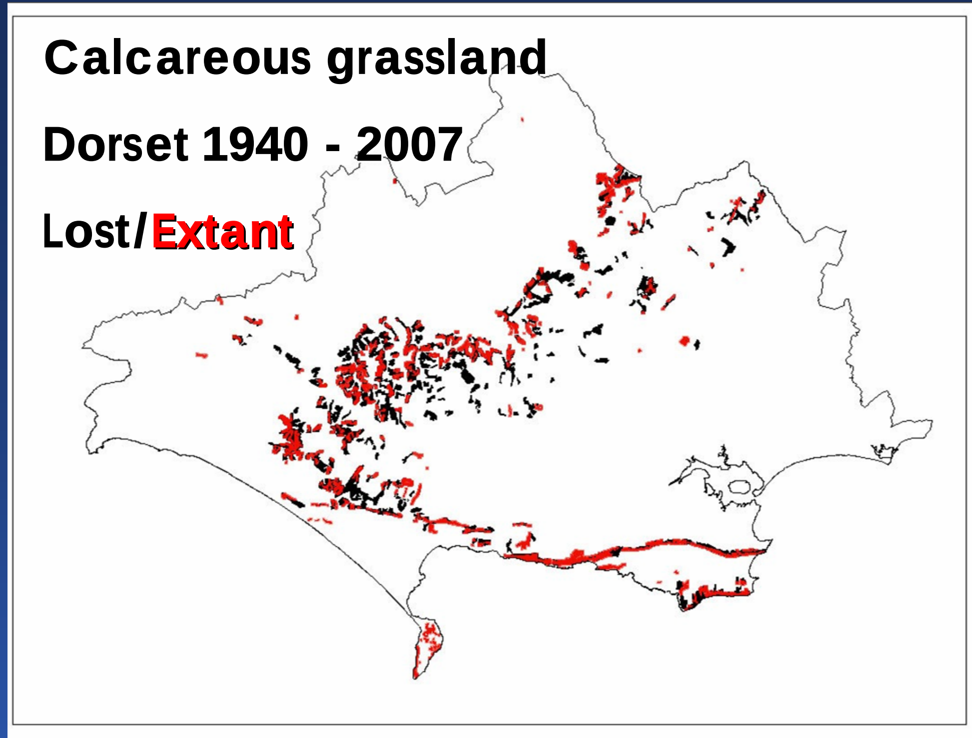
Biodiversity loss (a UK view) – extinctions

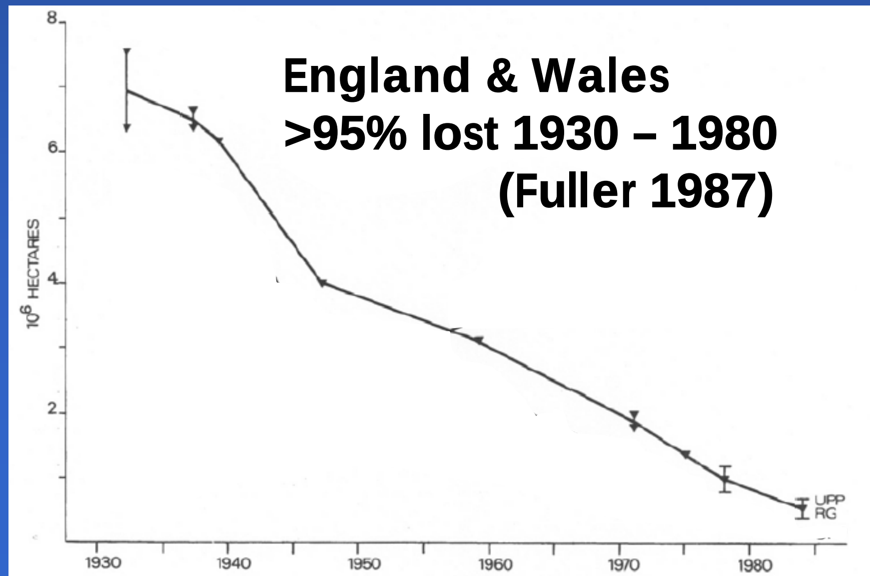
- Lady's slipper orchid (*Cypripedium calceolus)*
- Critically endangered in the UK
- 3 sites in the UK

- Interrupted brome (*Bromus interruptus)*
- Extinct in the wild in the UK

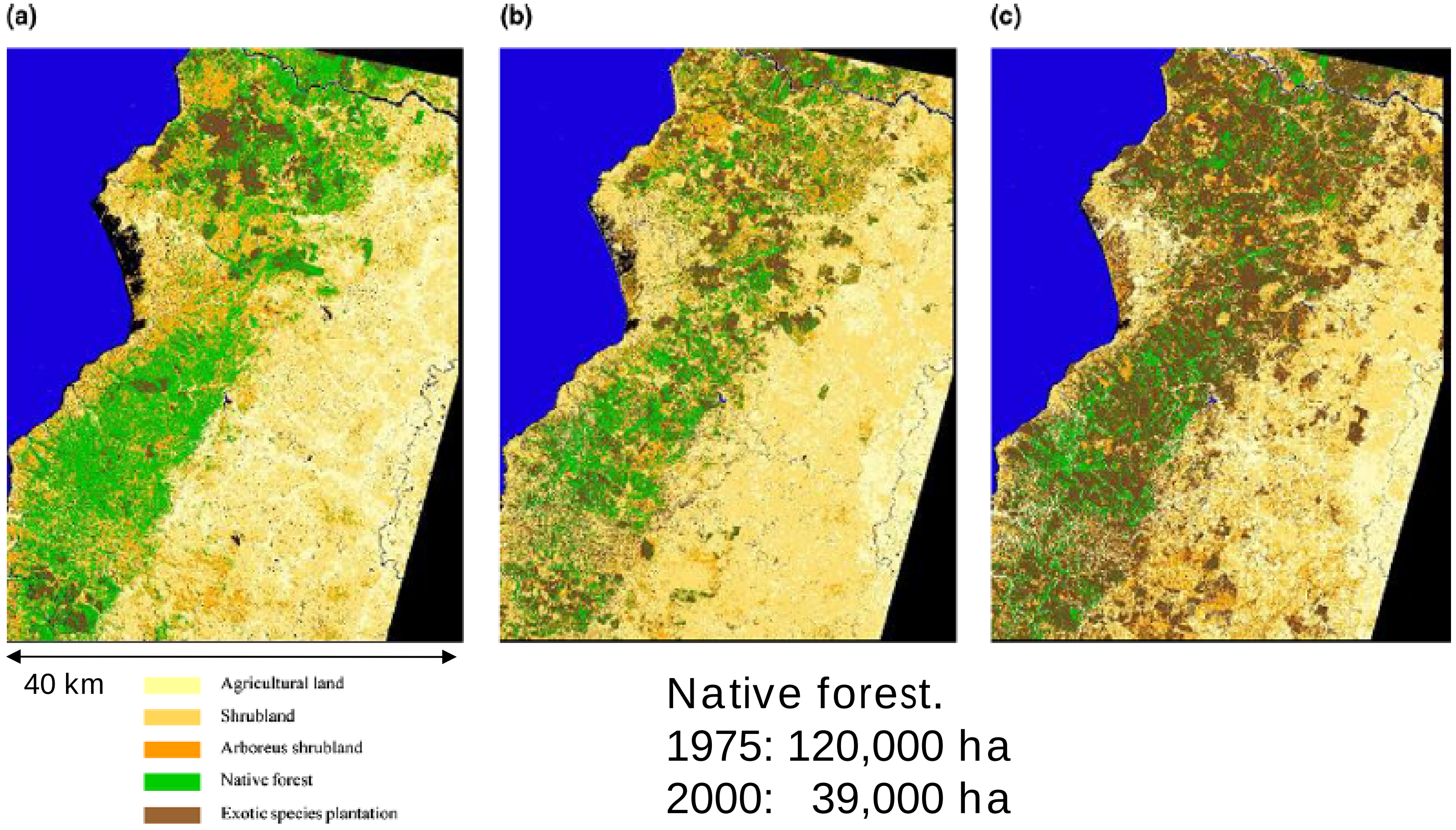
Habitat loss - UK

Semi-natural grassland





Habitat loss – Chilean temperate forests



Native forest.
1975: 120,000 ha
2000: 39,000 ha

Fig. 2 – Temporal and spatial variation of the major land cover types in Rio Maule-Cobquecura for the years: (a) 1975, (b) 1990, and (c) 2000.

Echeverria et al 2006

Doom & gloom – what can ecologists do?

Guardian 2007

Conserving individual species?

Habitat restoration - examples

Planting trees

Digging out river meanders

Amending contaminated soils

Removing alien plants

Restoration Ecology – a difficult history

- Generally seen as an engineering problem
- Has a poor theoretical basis
- Seen as a series of case studies – experimentation is difficult
- Low scientific impact
- Viewed with suspicion by many conservationists

RESTORATION: DISNEYLAND OR A NATIVE ECOSYSTEM?

by Constance I. Millar and William J. Libby

Let us be clear that we are unabashed fans of Disneyland. In our opinion, Disneyland is one of the finest things done for people by people. Among other things, it creates tangible fantasy and apparent reality, in ways that are pleasing to most of its visitors. But it is not reality; nor is it a natural ecosystem. Let us further assert that we believe the fantasy of a "Disneyland" to be better than the reality of another suburban parking lot. Similarly, if a truly native ecosystem cannot be restored, then we believe that the restoration of something biologically viable and sustainable is far preferable to the complete loss of that ecosystem.

What are some of the factors important for restoration that distinguish a "Disneyland" from a native ecosystem? One aspect that has been treated only superficially is the genetics of restoration. The genetic nature of introduced stock can profoundly influence the behavior of the individuals, which in turn may affect the dynamics of the entire community and disrupt or alter the course of co-evolution within the community. All of these effects are of great concern to the restorationist.

Most restorationists and ecological managers are aware in general of the consequences of using genetically inappropriate stock. They attempt to acquire material for restoration and re-introduction projects from within a reasonable distance from the project site – thirty to fifty miles, for example. But guidelines such as these are obviously rough ones that fail to consider the complex and irregular ways in which individual species vary genetically over the landscape. Some species vary gradually over large distances while others vary sharply over short distances. Within most species, many patterns can be found, depending on complex factors of the environment and history of the organisms. Each species has its own unique profile of genetic variation, which ideally would require a unique prescription for restoration.

Fortunately, there are some criteria which, though far from perfect, would be a big improvement over simple "collection radius" guidelines in many situations. In this article, we describe some of these guidelines and the experience behind them, and illustrate our hopes and concerns with examples drawn from our experience as forest geneticists.

The first is a restoration example in the loose sense that replanting or reseeding of trees after logging is a form of restoration. Before Redwood National Park was established in northern California, much of the land was owned and managed by timber companies. The exotic

Contamination of native stands of trees such as these Monterey Pines by foreign genes in wind blown pollen can occur over long distances. Photographs by William T. Follette unless otherwise noted.

species Monterey pine (*Pinus radiata*) had been planted in a few places. Other logged areas were aerially seeded, using seeds of coast redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), and Sitka spruce (*Picea sitchensis*). These species, though native to the

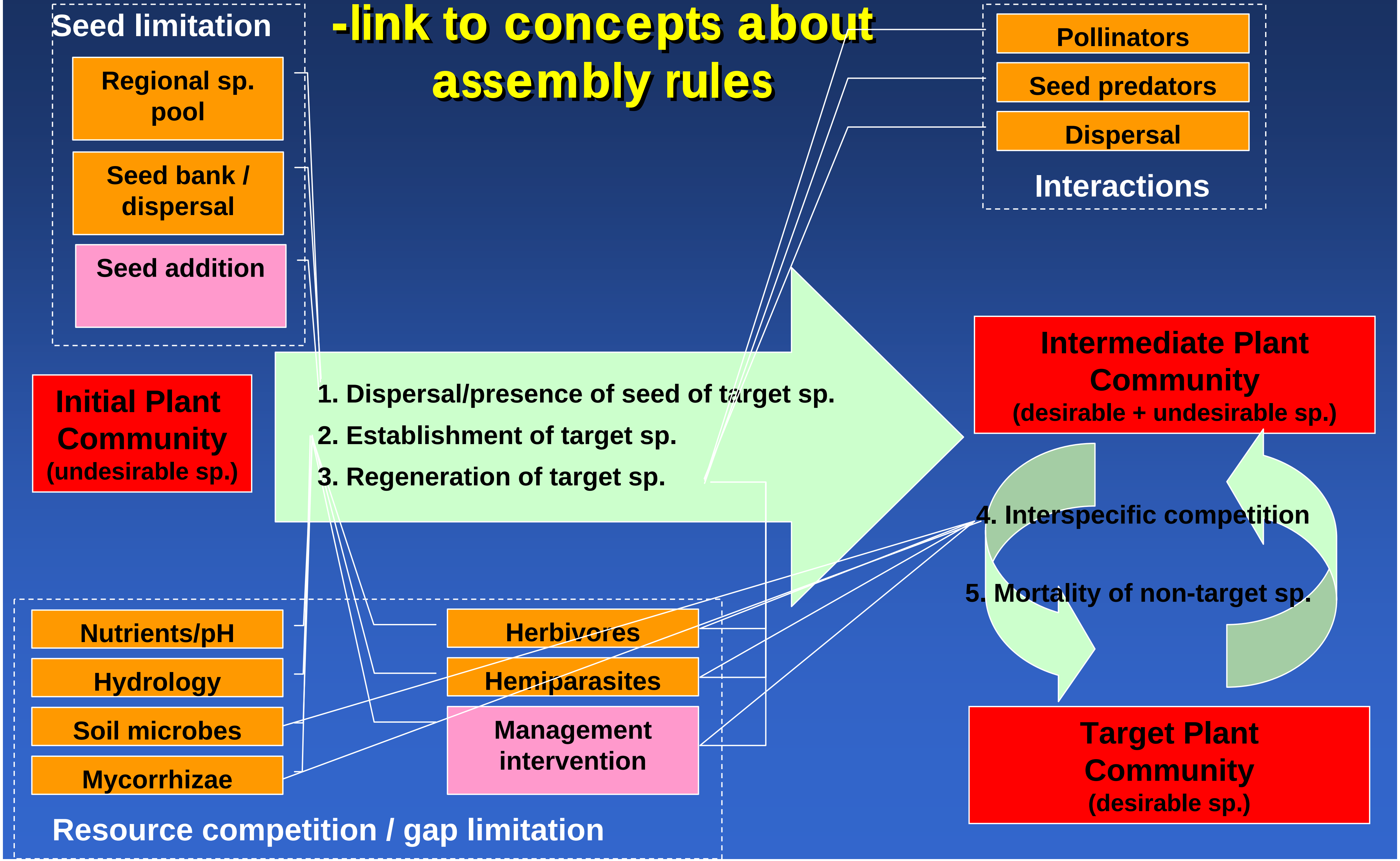
3

Restoration Ecology – comedy or tragedy?

A happy ending?

Or ‘signifying nothing’?

1) Experiments to test restoration methods -link to concepts about assembly rules

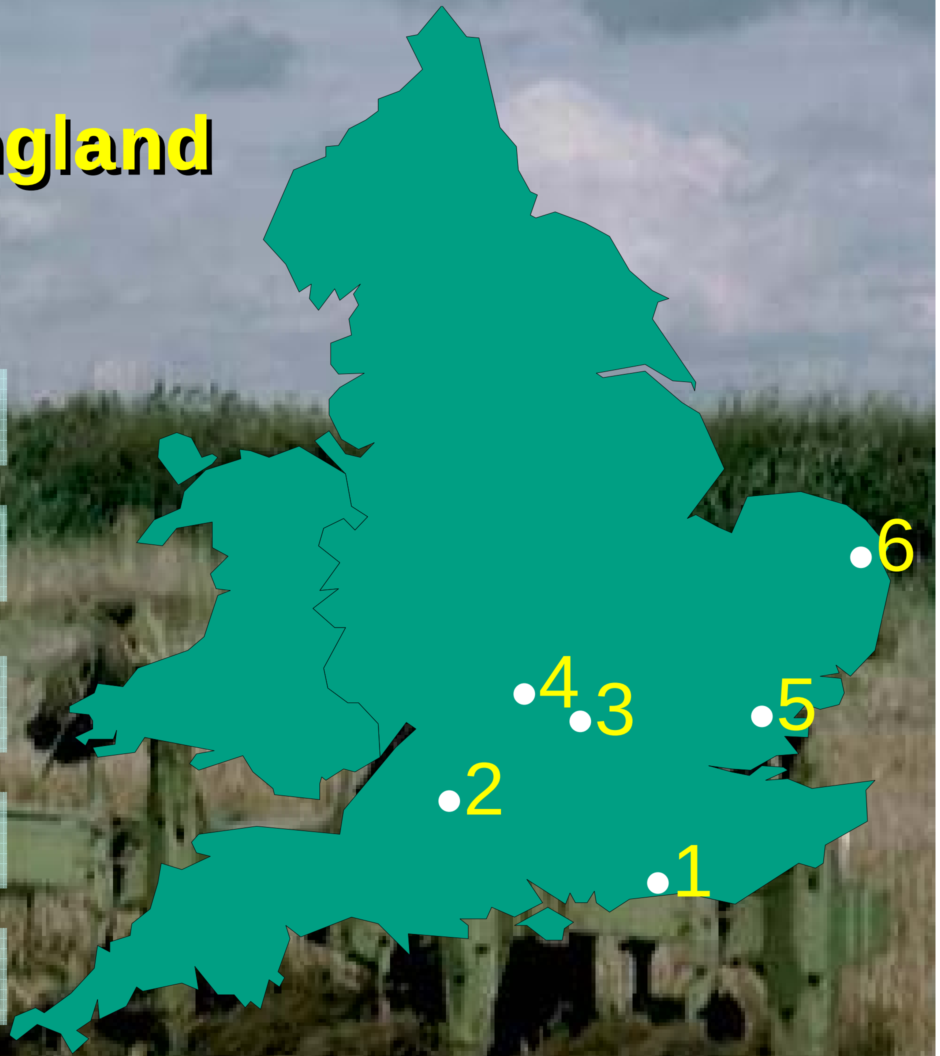


Creating new grassland on arable land

Experiment at 6 sites across S England

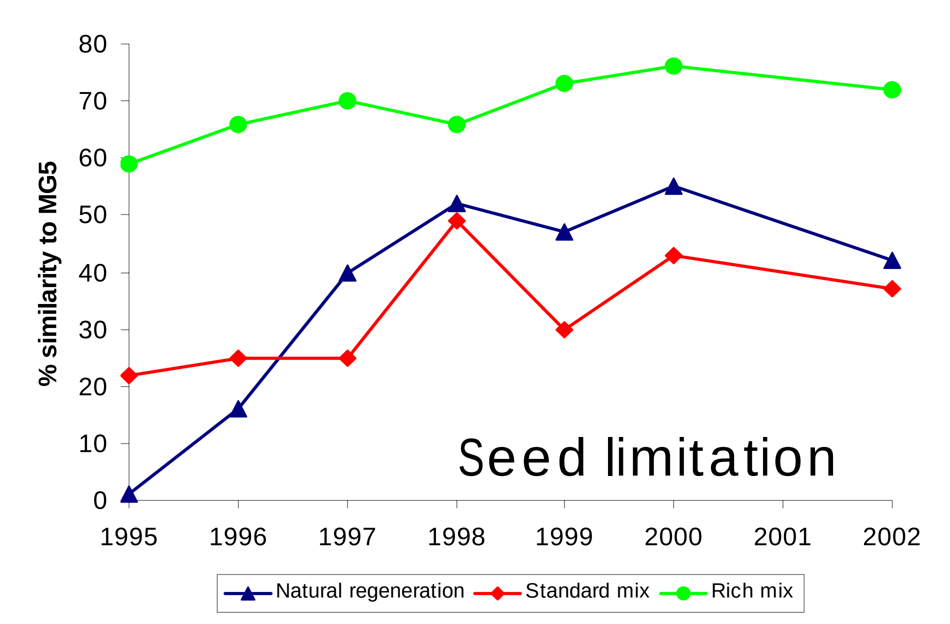
Hypothesised limiting factors

- Seed limitation
- High soil nutrients
- Lack of facilitation (Nurse crops)
- Age (Succession)



Pywell et al (2002). J. Appl. Ecol

Over-riding factor = seed limitation



Pywell et al (2002). J. Appl. Ecol

Diversifying species-poor grassland

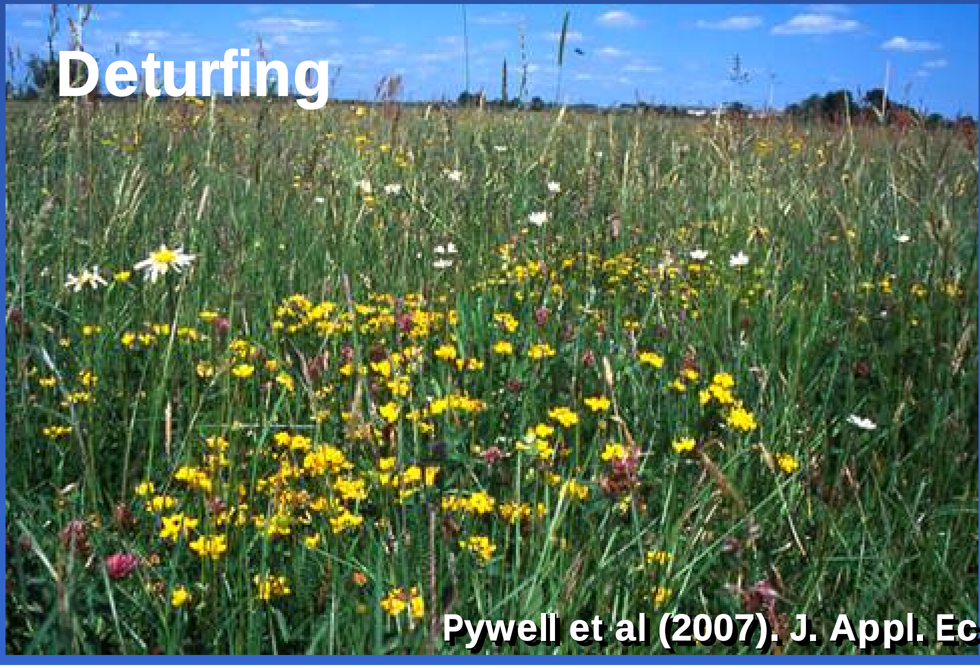
Hypothesised important factors

- Disturbance intensity
- Seed limitation
- Management – grazing, hay-making
- Soil nutrients
- Invert herbivory

Pywell et al (2007). J. Appl. Ecol

Diversifying species-poor grassland

- Main factor = disturbance intensity
- 19 species added
- 10-13 established in de-turfed
- 3-4 in others
- Difficult to diversify

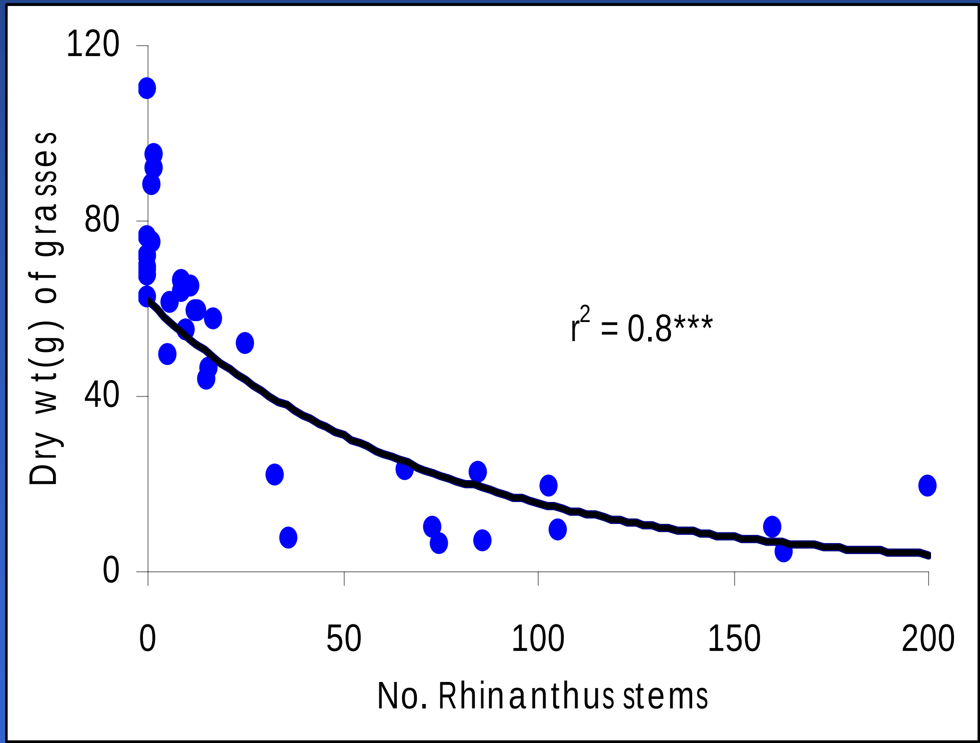


Pywell et al (2007). J. Appl. Ecol

New approaches – Keystone species

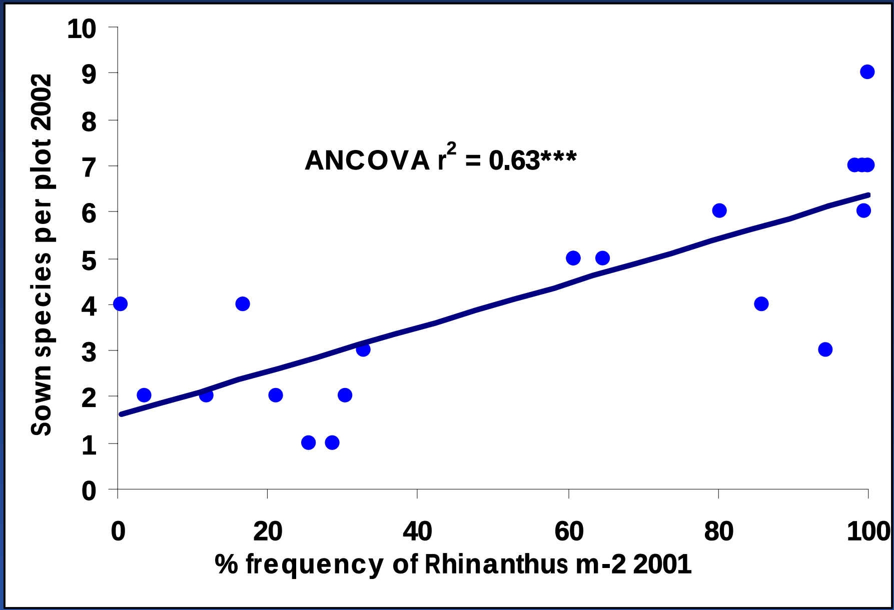
Yellow rattle

- A hemi-parasite
- Typical of species-rich grasslands
- Decreases grassland productivity



Pywell et al (2005). J. Appl. Ecol

Rhinanthus increases sown species' establishment



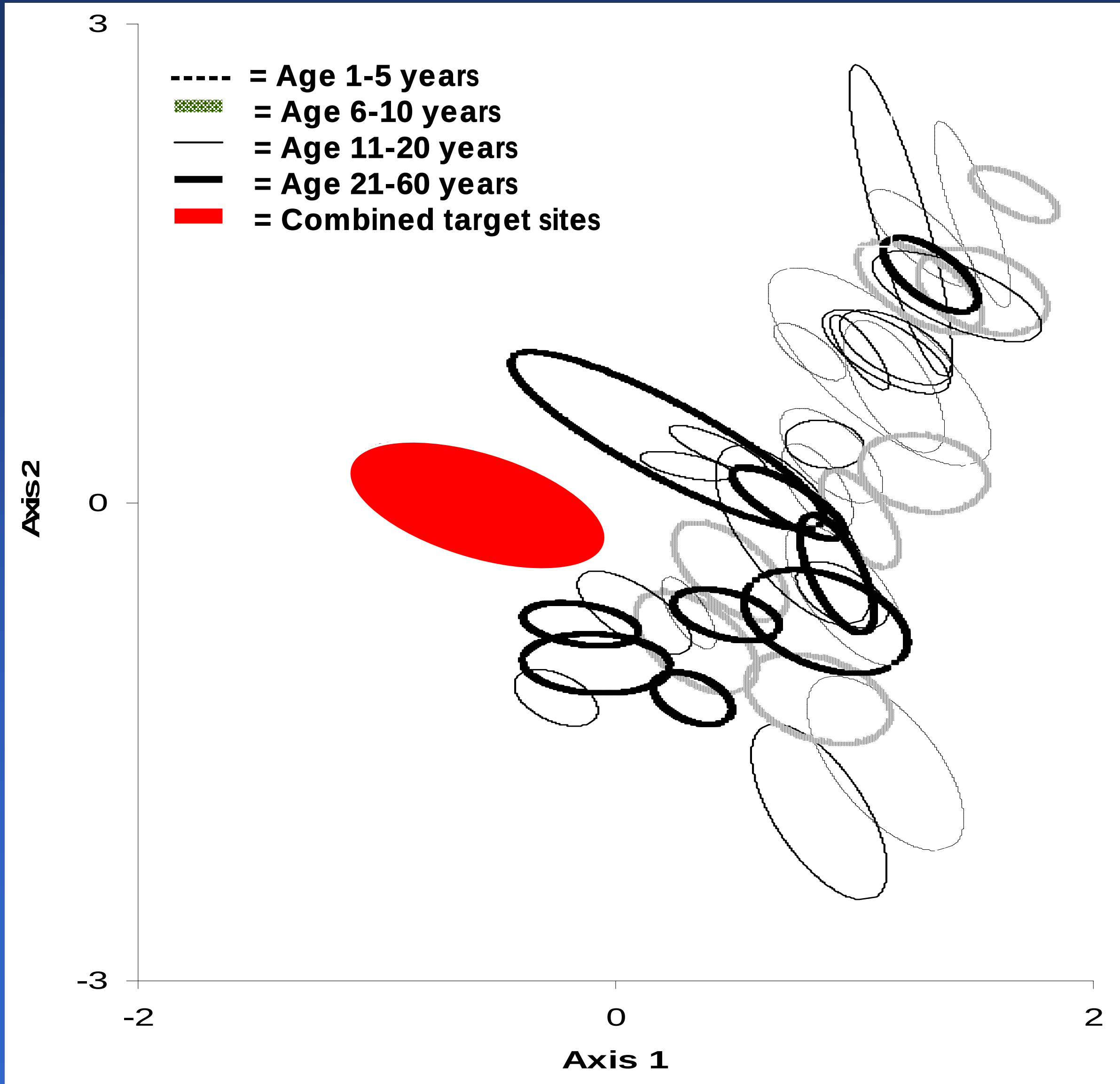
Frequency	Correlation *Rhinanthus*
Achillea millefolium	**0.59****
Centaurea nigra	**0.59****
Hypochoeris radicata	0.20nsd
Leontodon autumnalis	**0.48***
Leontodon hispidus	0.37nsd
Leucanthemum vulgare	**0.52***
Lotus corniculatus	0.15nsd
Plantago lanceolata	**0.83*****
Prunella vulgaris	**0.49***
Trifolium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





Pywell et al (2005). J. Appl. Ecol

2) Can restoration perfectly recreate communities?



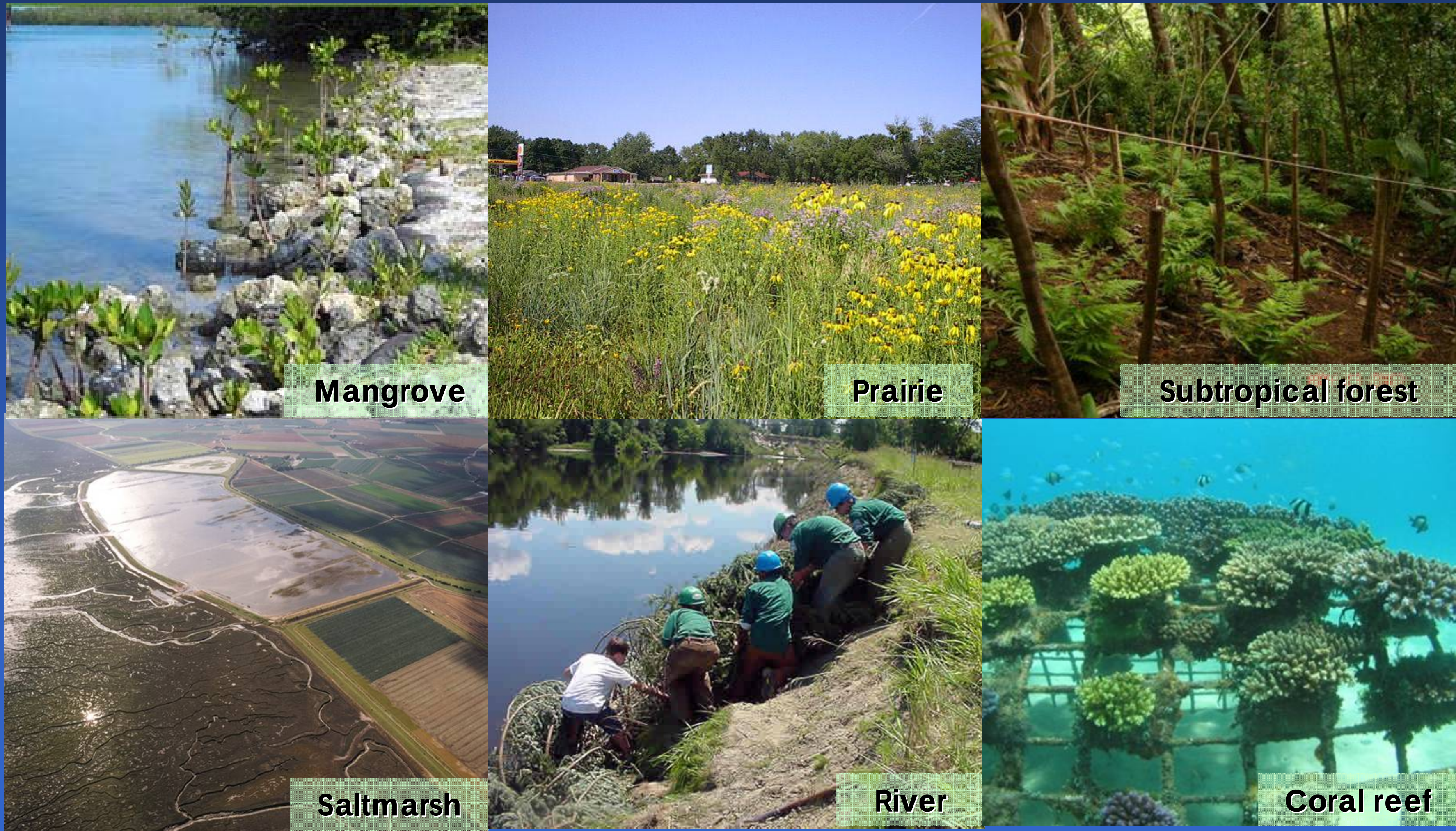
- Survey of 80 sites in southern England

- Restored grasslands come to resemble ancient grasslands, *but not completely*

Fagan et al. (2008) J. Appl. Ecol

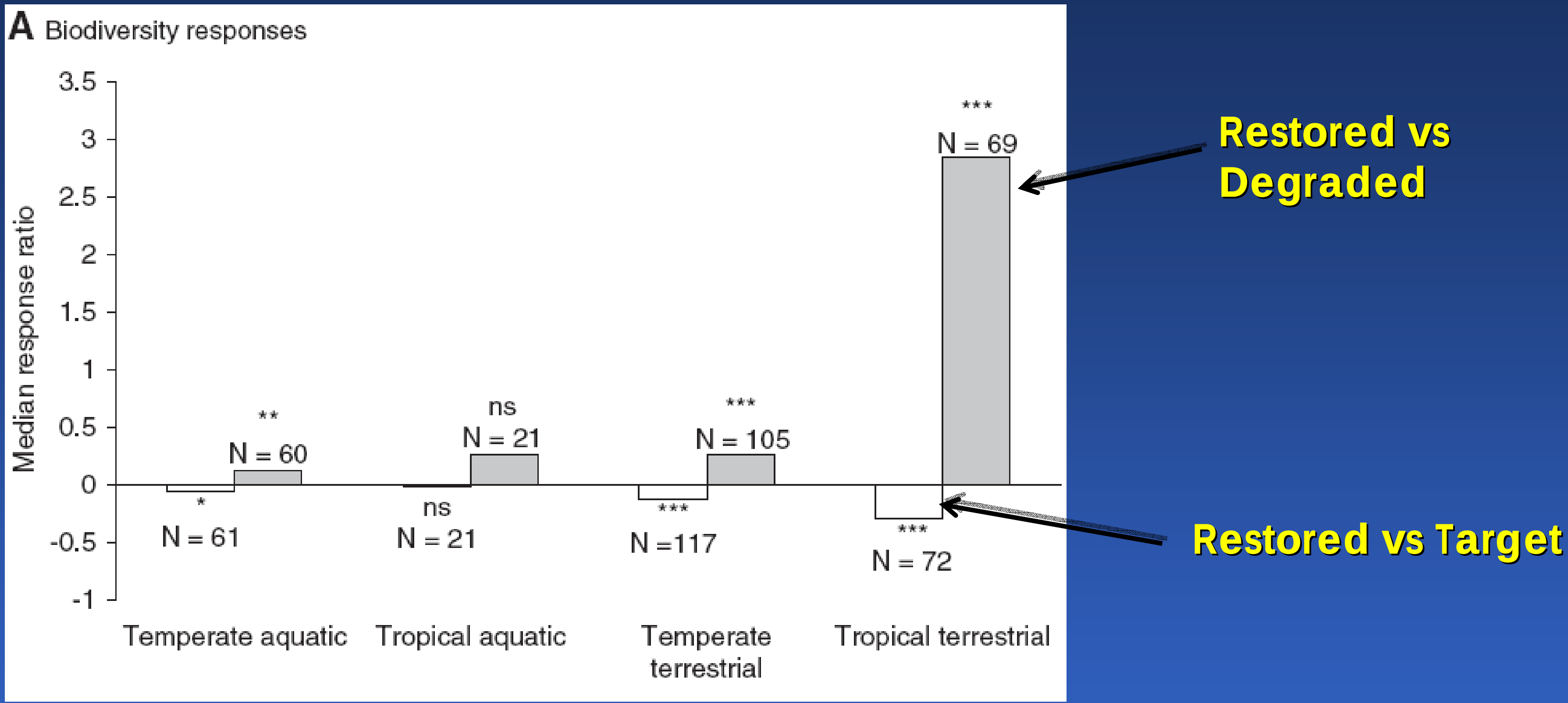
Global meta-analysis of success in restoration projects

89 restorations across the world – tropical/temperate, aquatic/terrestrial



Rey Benayas et al. (2009) Science

Restorations are only partly successful



Restored systems have lower biodiversity than target (86%)
- but have 44% more biodiversity than degraded systems

But, differences among biomes

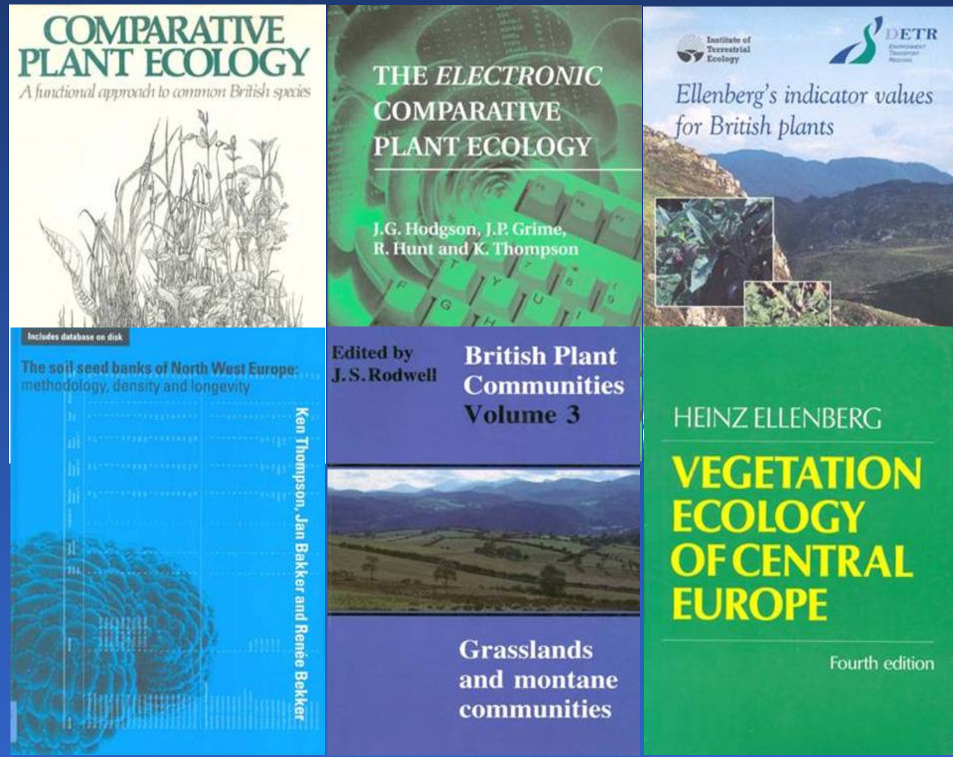
Rey Benayas et al. (2009) Science

What limits restoration success?

Analyse characteristics of poor and well performing species in grassland restorations

Poor performers

- Specialist, stress-tolerating, rare species with smaller geographic range



Good performers

- Generalist, competitive, good-dispersing species of fertile habitats

Fagan et al. (2008) J. Appl. Ecol, Pywell et al (2003). J. Appl. Ecol

New work – improving success

New methods to establish “difficult” plants

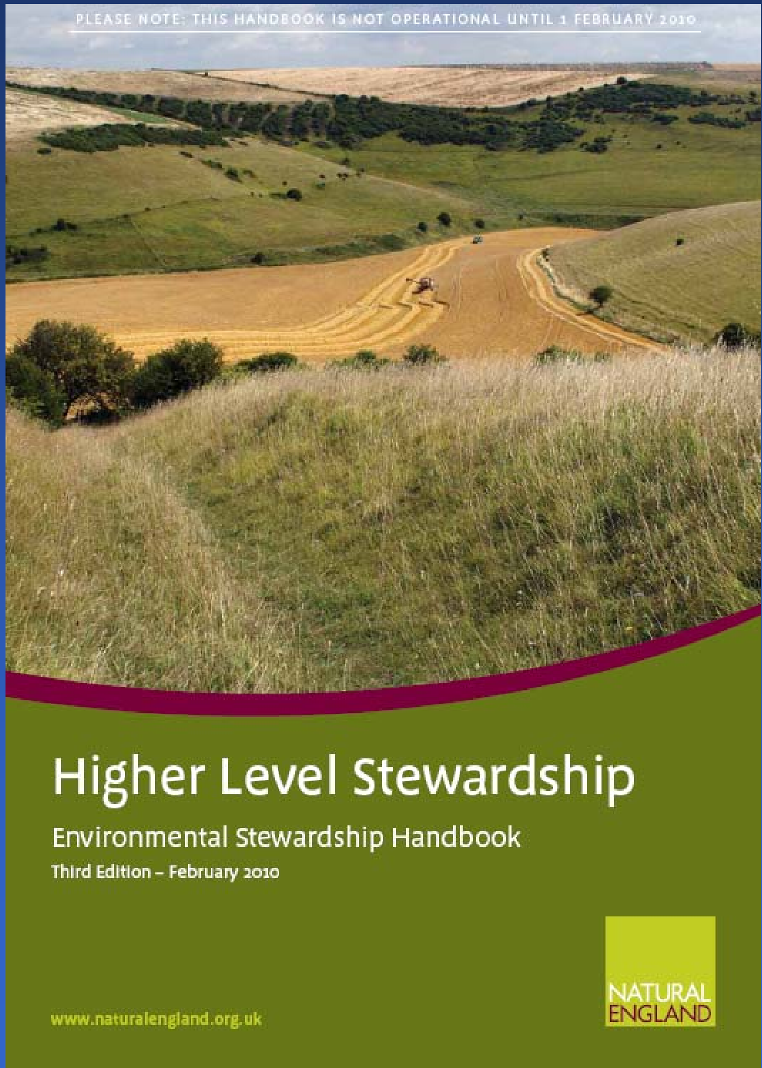
Helianthemum nummularium

Campanula glomerata

Filipendula vulgaris

Stachys officinalis

3) Informing policy about restoration & conservation – agri-environment schemes



Species-rich hay meadow with great burnet, lady's bedstraw and rough hawkbit

HK8 Creation of species-rich, semi-natural grassland £280 per ha

This option is aimed at creating species-rich grassland on former arable land, ley grassland or set-aside. The creation of species-rich grassland is very demanding and will be feasible only in a few situations. Potential for this option will depend on soil type, pH and soil nutrient status (particularly the amount of available phosphorus). This option will normally be targeted at sites close to existing species-rich grassland.

Creation of a species-rich grassland will include establishing the sward by natural regeneration or using a seed source or mixture recommended by your Natural England adviser. The sward will need to be cut or grazed in the first year to encourage the grasses to tiller and to control annual weeds. Once established, management will be the same as for HK6.

2,373 ha under HK8 in England 2009

Farmer engagement & AES

Linking ecology & social science

- Mostly limited engagement with AES objectives
- Or understanding of reasoning behind prescriptions
- Unintentional breaches & corner-cutting
- Linked to poor outcomes of AES
- Problem of scheme based mostly on monetary incentives?

The FARMCAT project

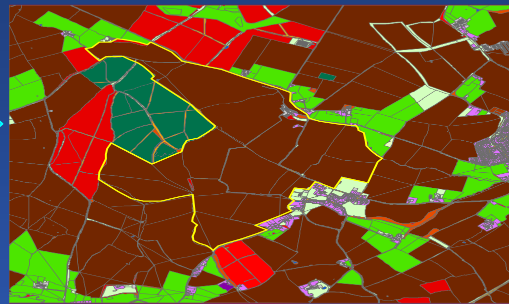
Enhancing the success of agri-environment schemes

FarmCAT Improving agri-environment schemes

Training

Application of AES options

Landscape context



Farmer attitude to & benefits from AES

Biodiversity enhancement

RURAL ECONOMY AND LAND USE

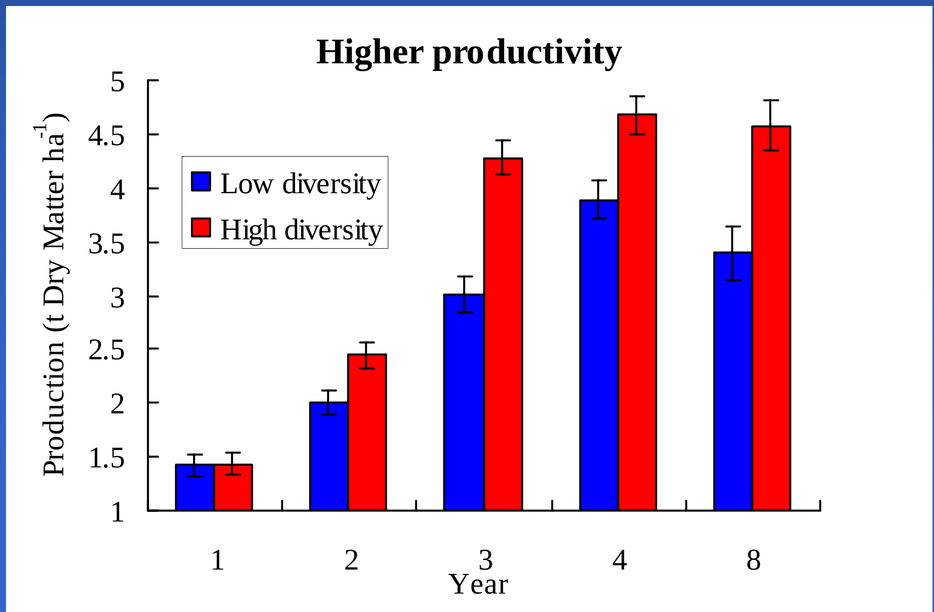
Farmer motivations & training

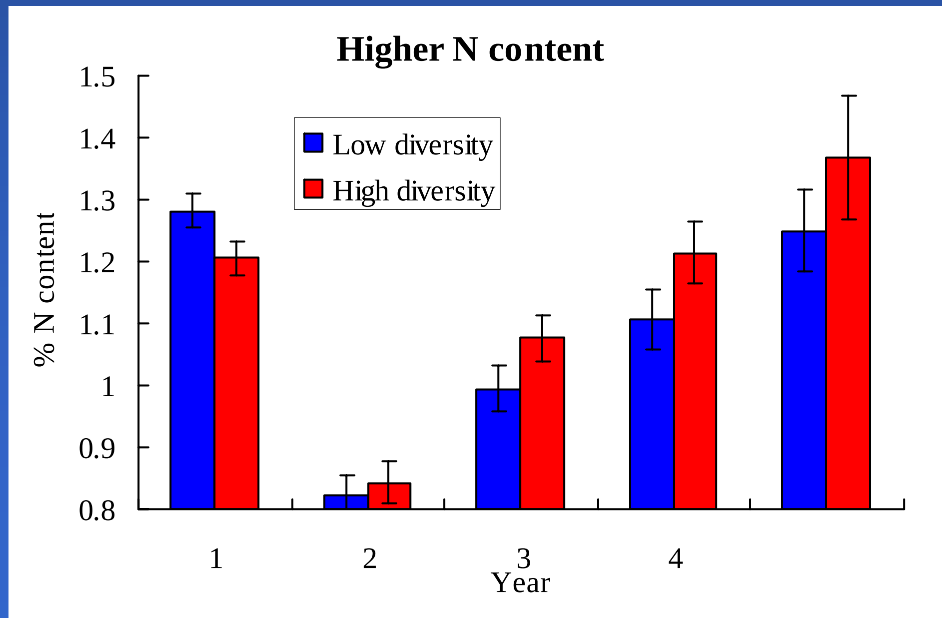
- ***Overall, how useful did you find the information presented today?***
  - **68% (17 farmers) – Very useful (32% useful)**
- ***Is the training likely to influence the way you think about environmental land management in general?***
  - **93% (26 farmers) - Yes**
- ***Is the training likely to influence the way you manage your ELS land?***
  - **90% (25 farmers) - Yes**
- ***Would you recommend this training event to a farming friend?***
  - **100% Yes**

4) Linking restoration with wider societal needs

The need to consider conservation alongside other objectives

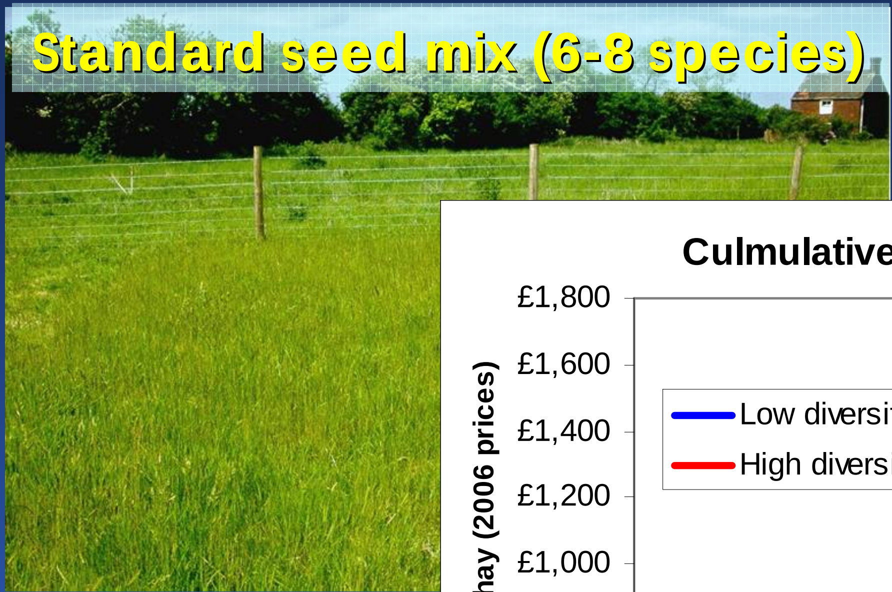
Linking biodiversity & agricultural production

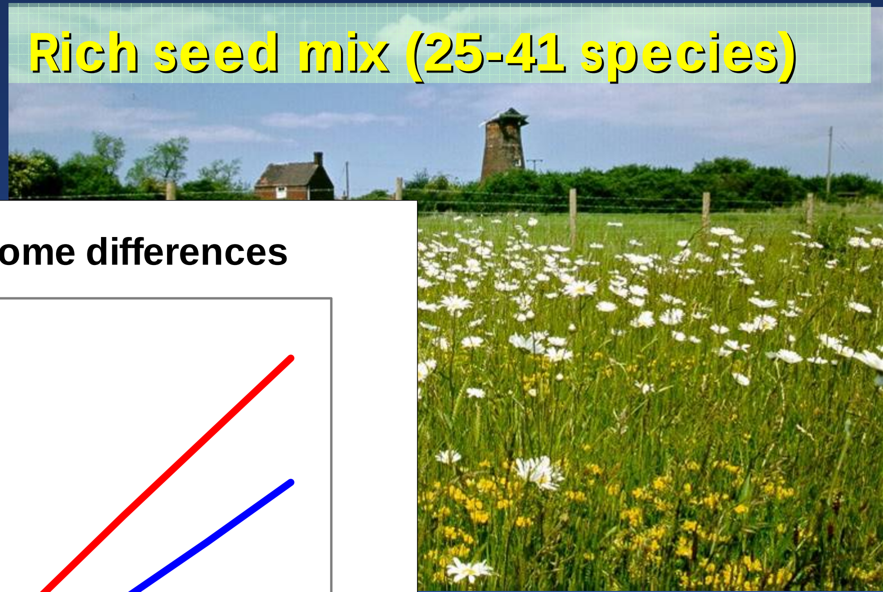


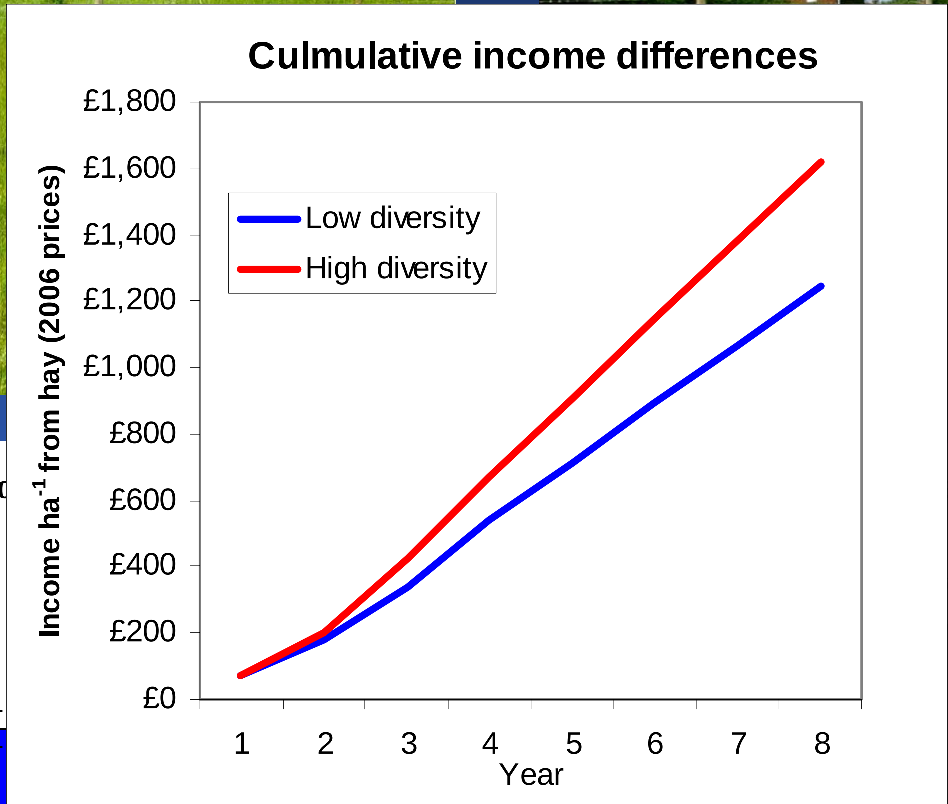


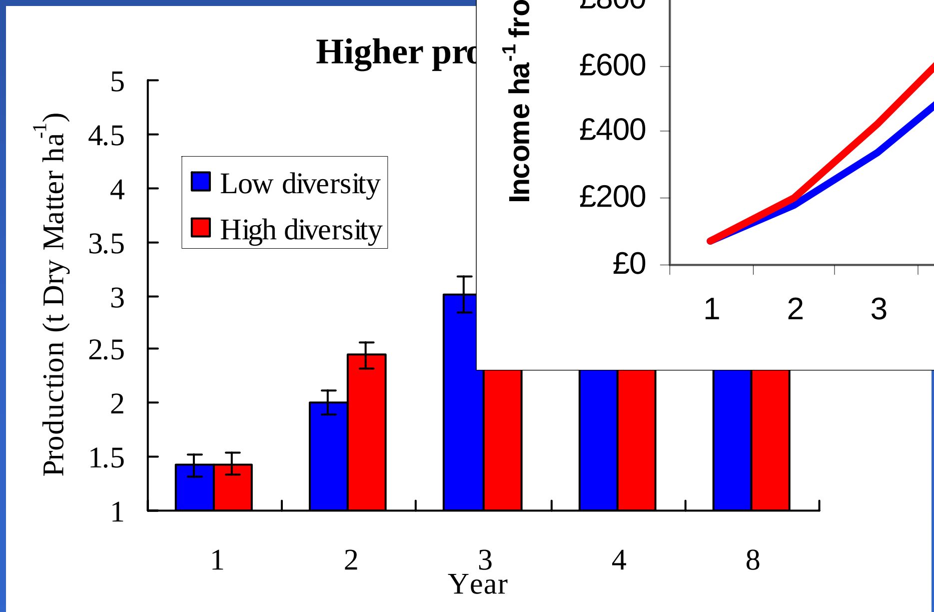
Bullock et al (2001) Ecol. Lett., (2007). J. Appl. Ecol.

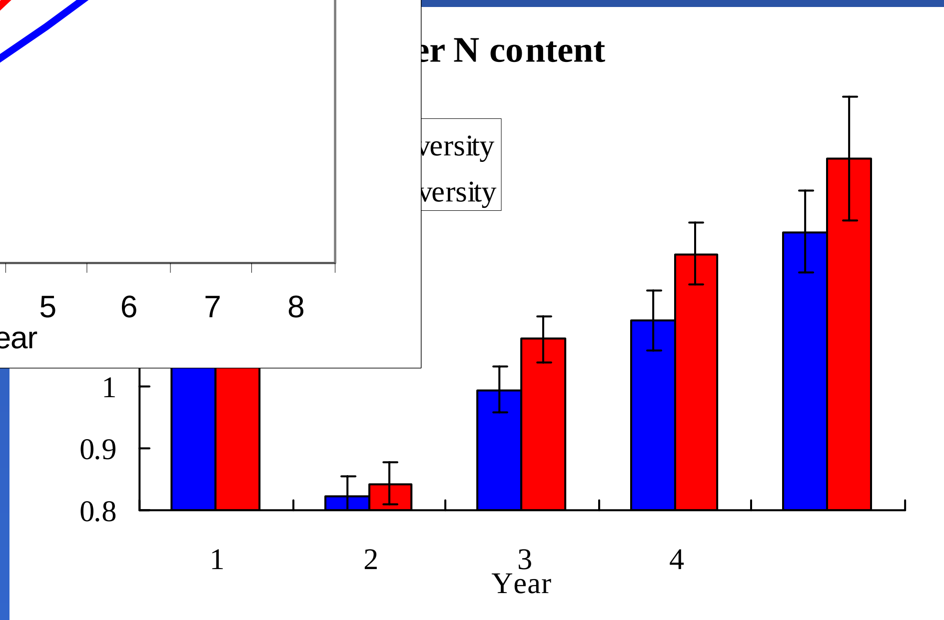
Linking biodiversity & agricultural production







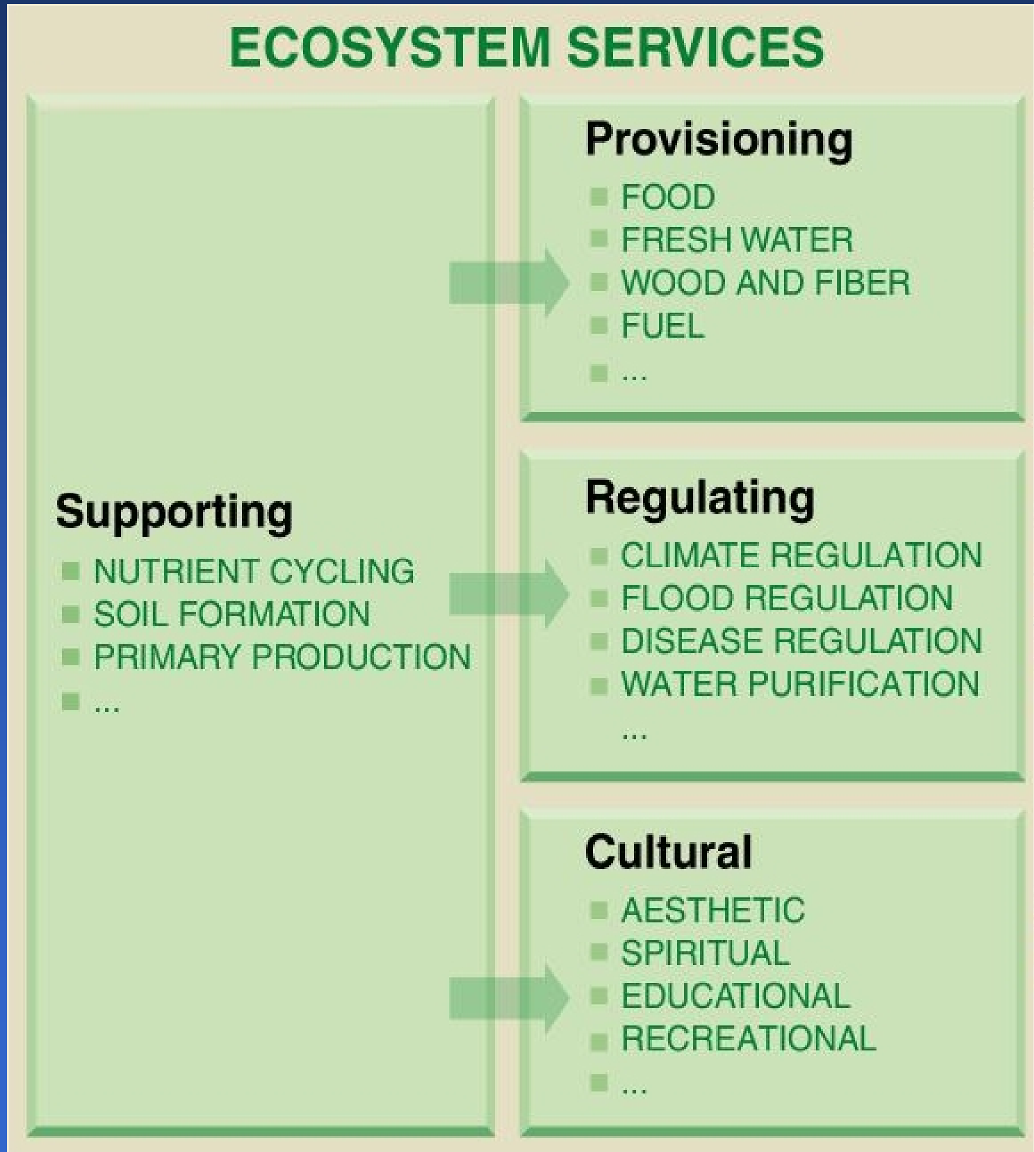




Bullock et al (2001) Ecol. Lett., (2007). J. Appl. Ecol.

Restoration and ecosystem services

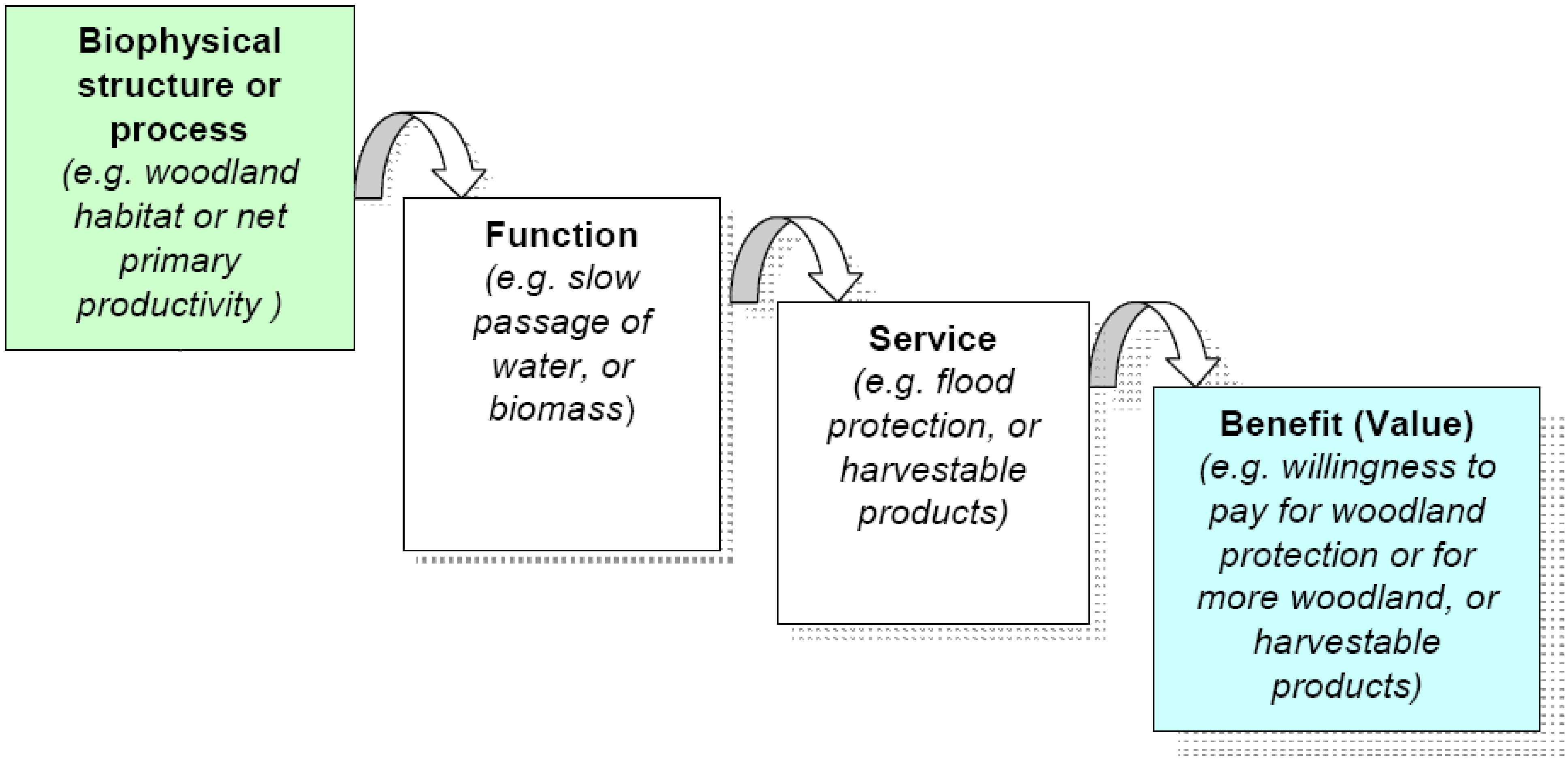
The ecosystem service concept



From Millennium Ecosystem Assessment

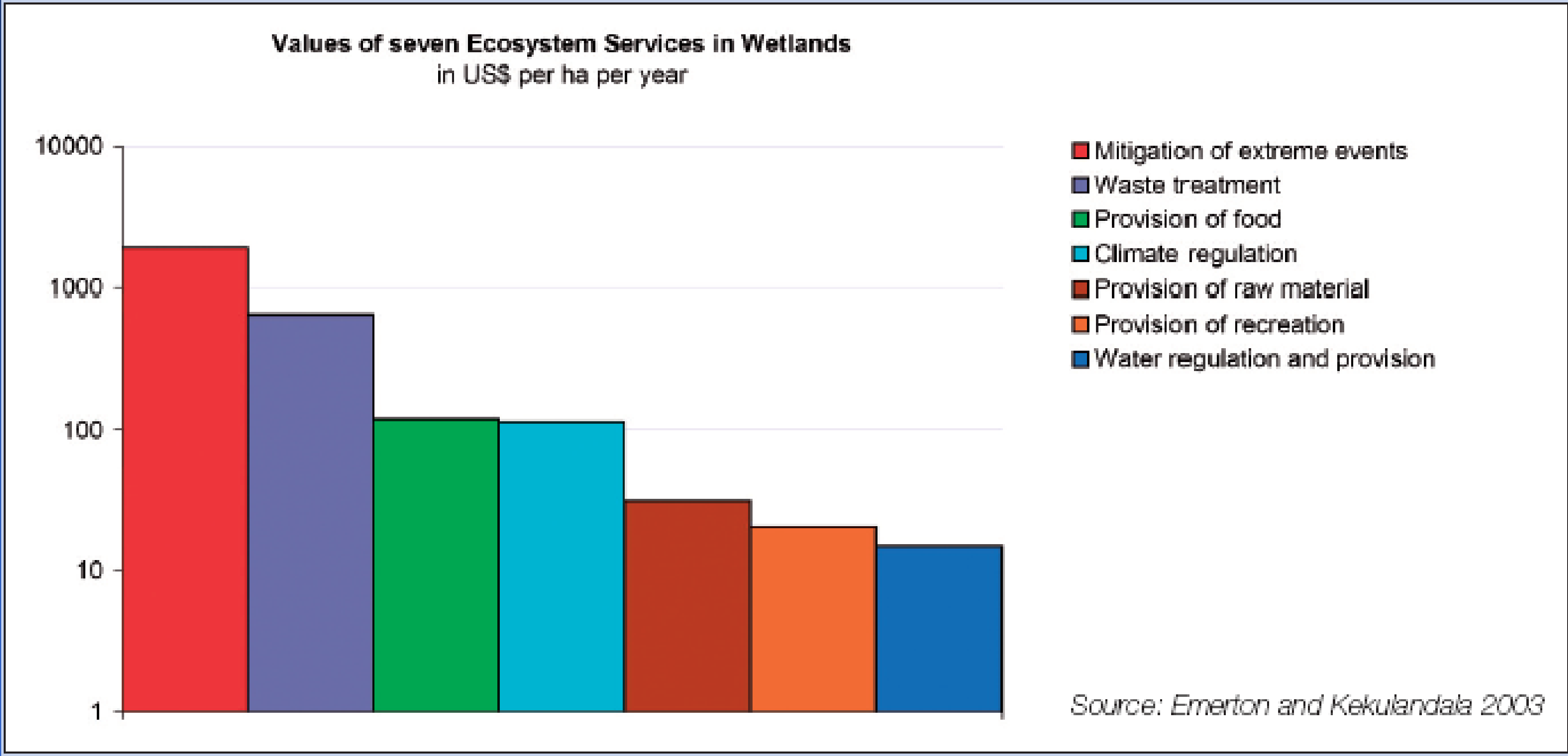
Restoration and ecosystem services

The ecosystem service concept

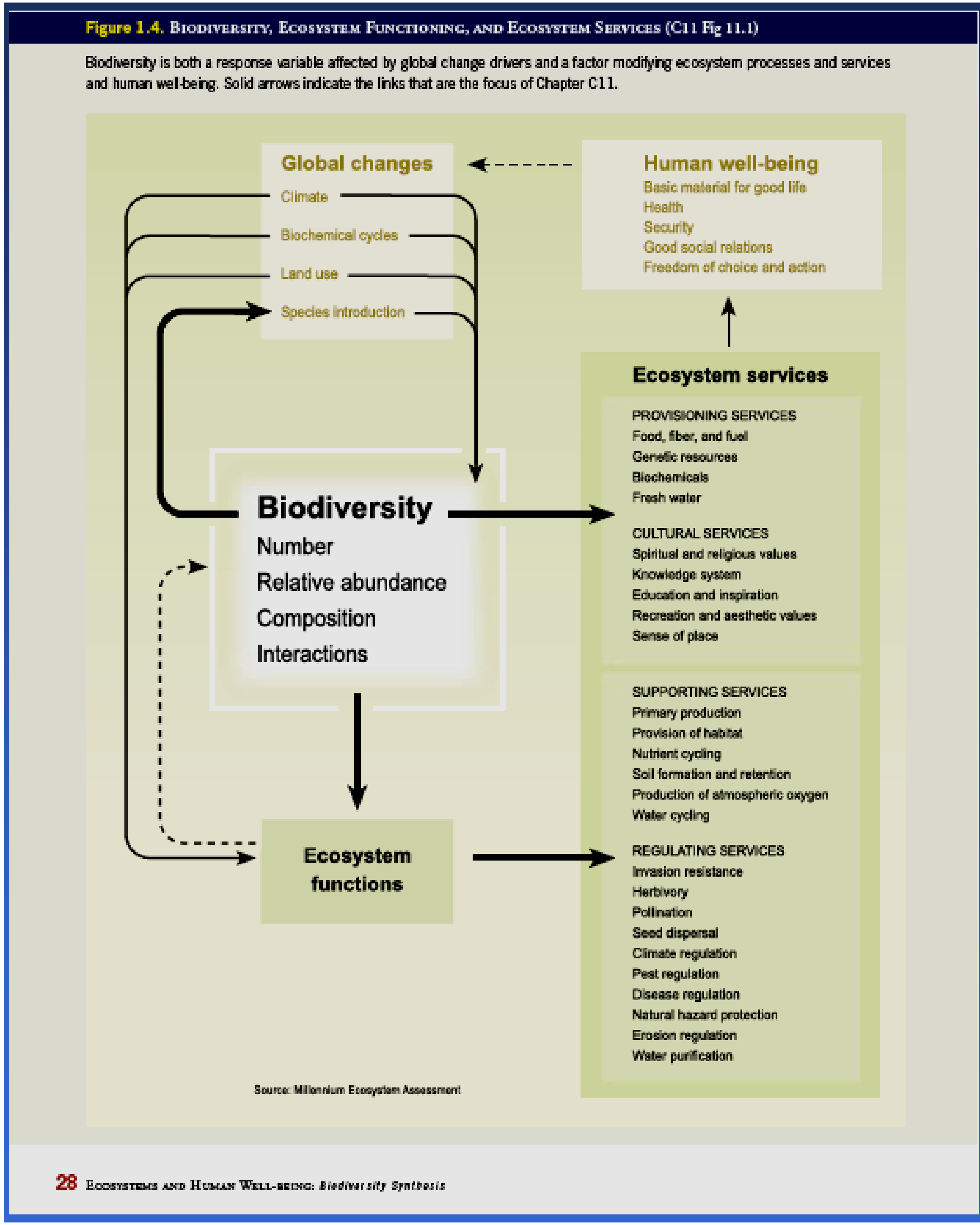


Haines-Young & Potvin

Leading to valuation of ecosystem services



From TEEB



Outstanding questions

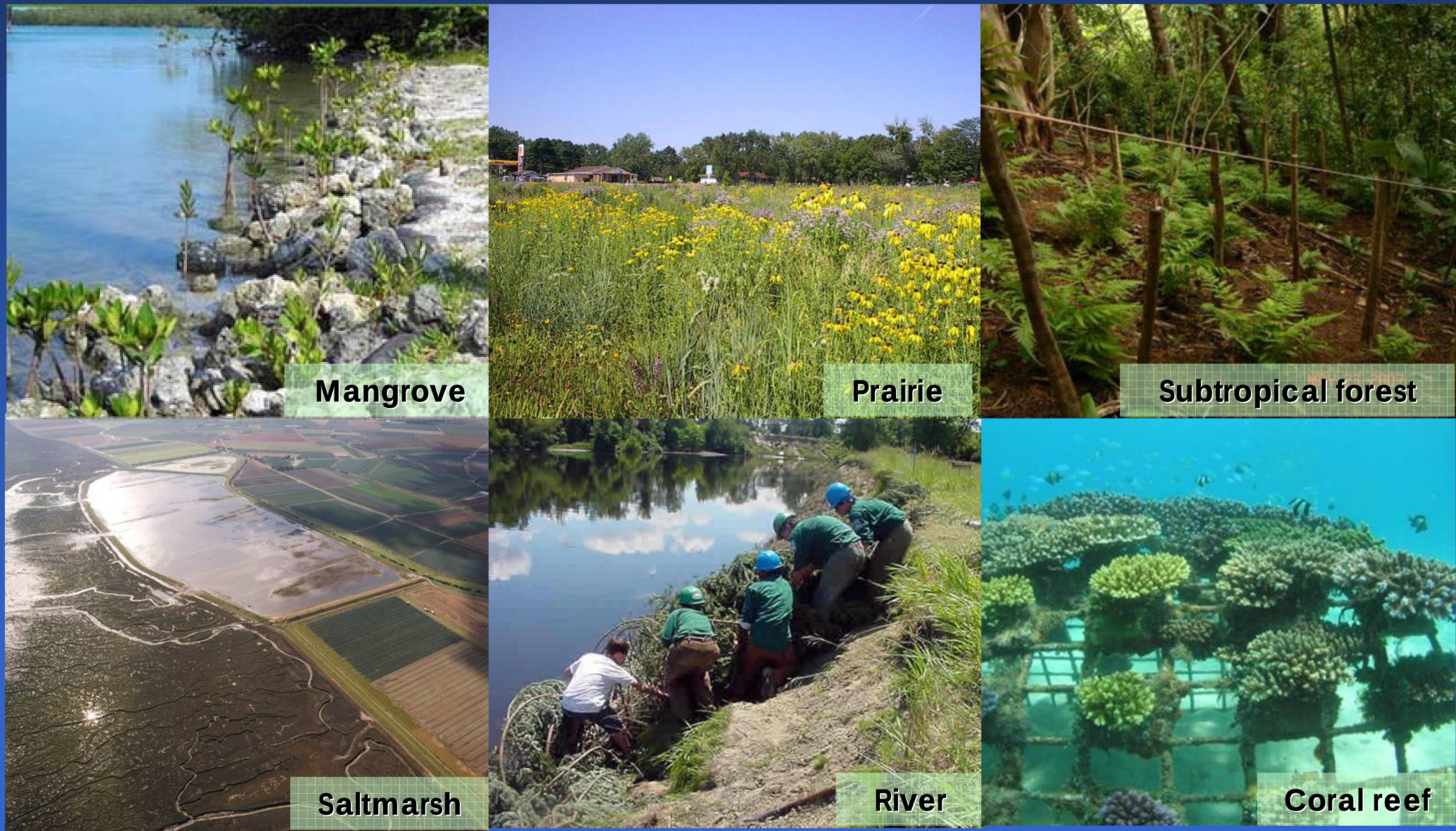
- How is biodiversity linked to ecosystem services?

- Can restoration be used to enhance biodversity & ecosystem services

From Millennium Ecosystem Assessment

Global meta-analysis of ecosystem services in restoration projects

89 restorations across the world – tropical/temperate, aquatic/terrestrial

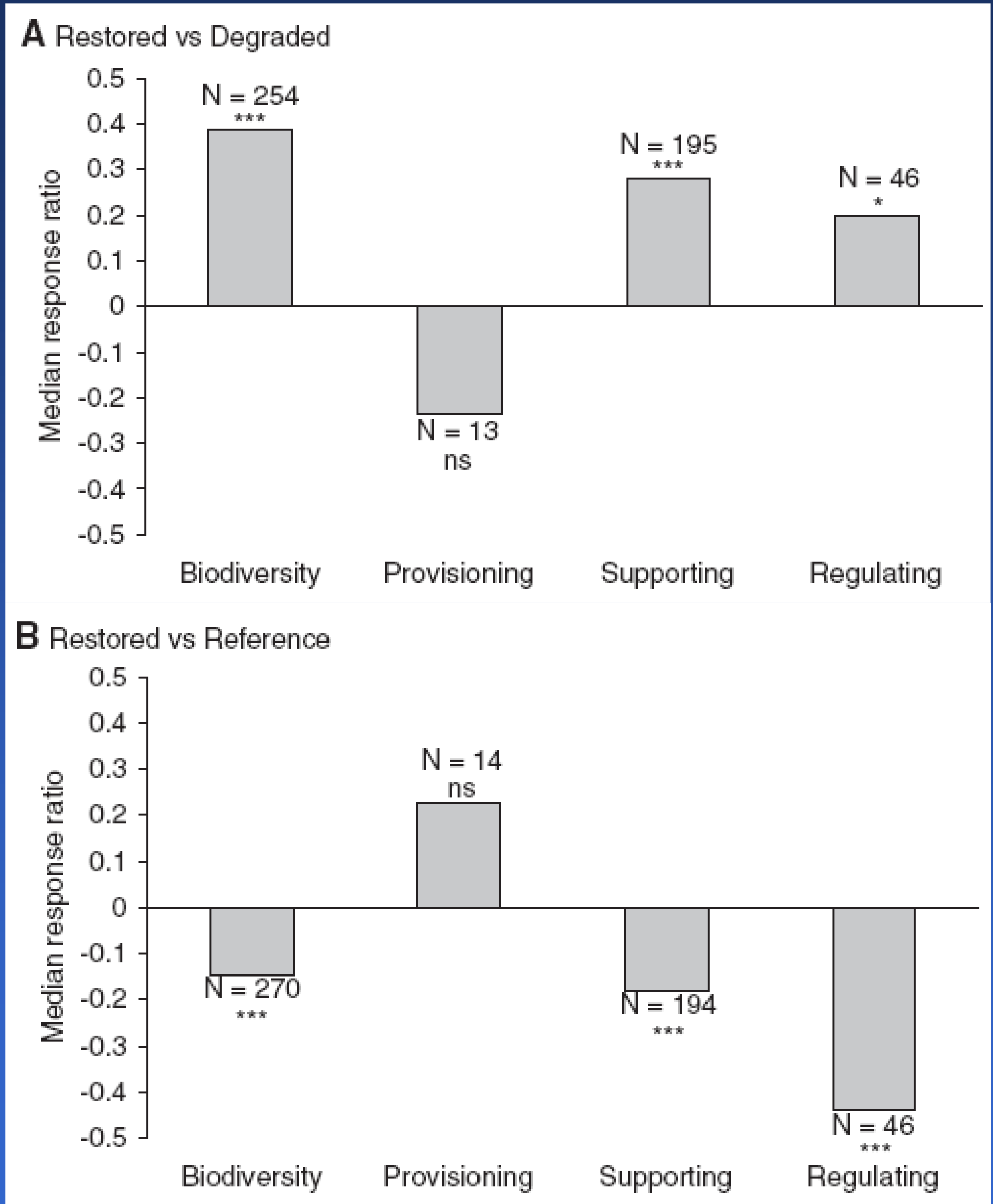


Rey Benayas et al. (2009) Science

Relating function measures to services
(Biodiversity = all trophic levels)

Provisioning Services	Regulating Services	Supporting Services
Commercial crab production	Thermal buffer capacity	Soil compaction
Fish biomass	Runoff coefficient	Total C
Density of commercial trees	Water quality	Salinity
Eel abundance	Total Pb	Soil respiration
Preference by livestock	Sedimentation	Denitrification potential

Restorations are (partly) successful



- Degraded systems have ~55% biodiversity & services of pristine systems

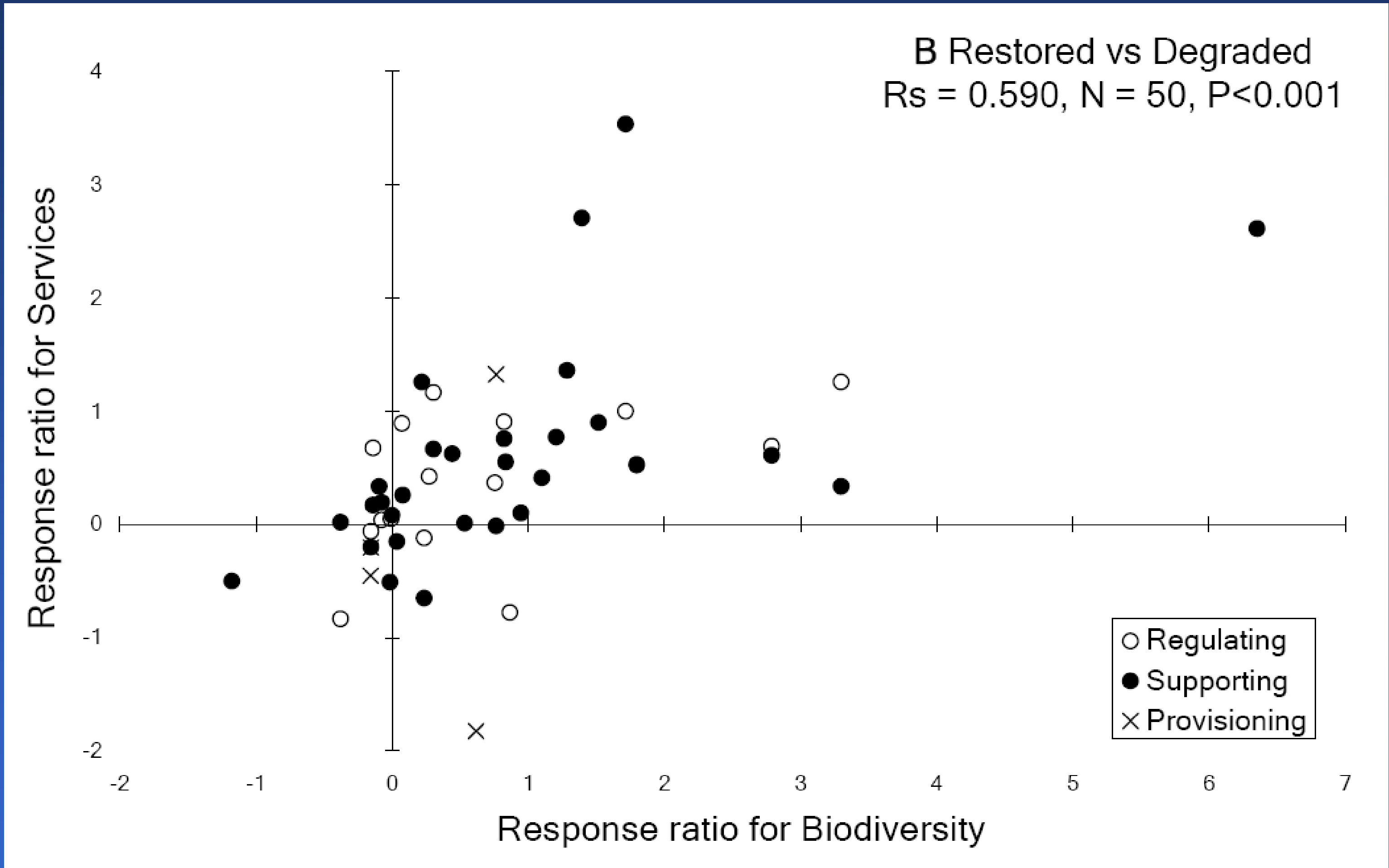
- Biodiversity increased by restoration (144%)

- Services increased by restoration (125%)

- But pristine systems are better than restored (~80%)

Rey Benayas et al. (2009) Science

Increasing biodiversity correlated with increasing services

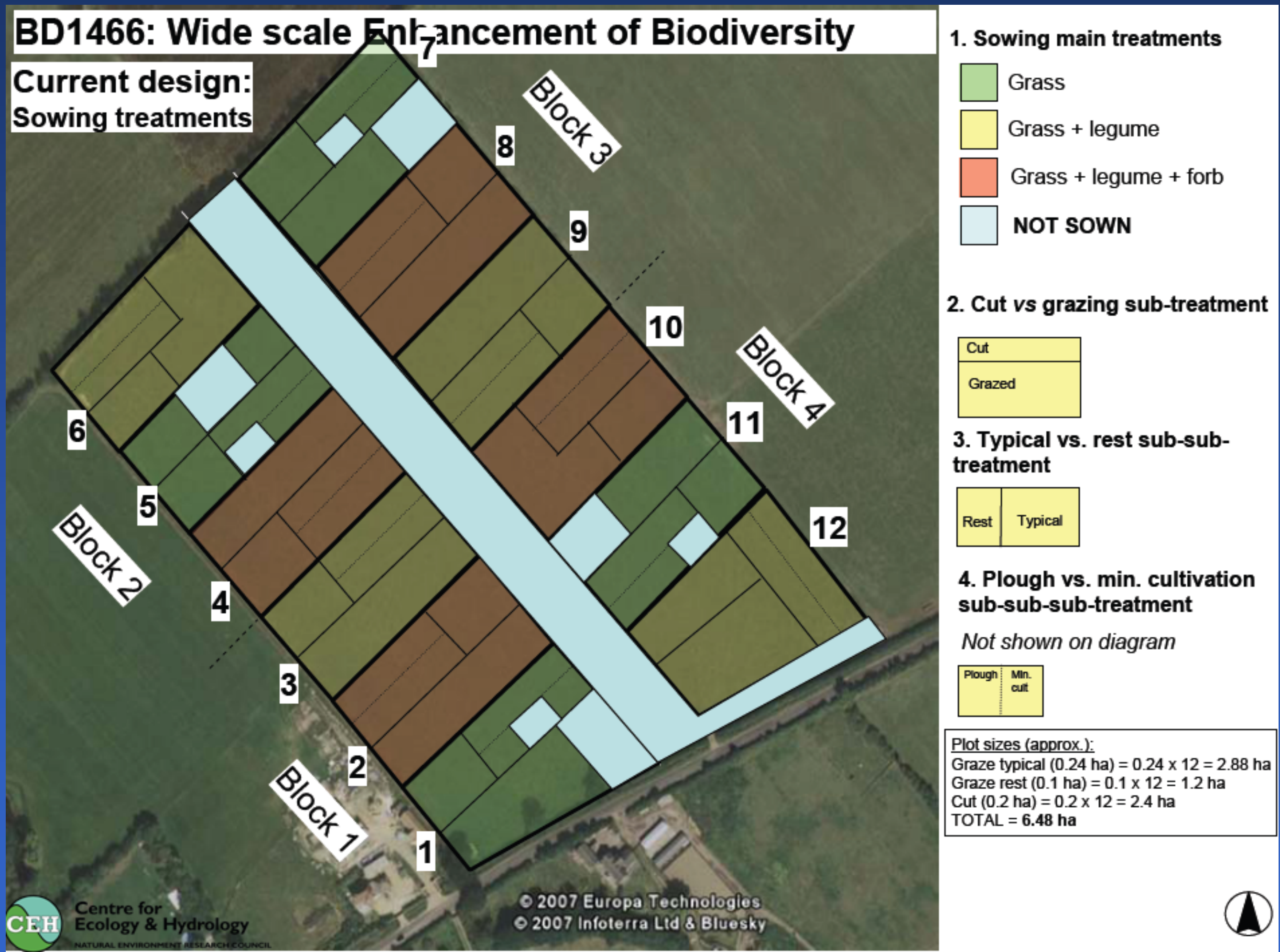


- **Important evidence for link between biodiversity & services**

- **Restoration can enhance both simultaneously**

Rey Benayas et al. (2009) Science

New policy:
Restoration to enhance biodiversity & ecosystem services



New experiment
Effects of added plants on:

- **Production: amount & quality**
- **Butterflies, bumblebees**
- **Birds**
- **Nutrient leaching**
- **Soil structure**
- **Carbon dynamics**

Using Ecosystem Services to calculate value of restorations

Table 3: Estimates of costs and benefits of restoration projects in different biomes

	Biome/Ecosystem	Typical cost of restoration (high scenario)	Estimated annual benefits from restoration (avg. scenario)	Net present value of benefits over 40 years	Internal rate of return	Benefit/cost ratio
		US$/ha	US$/ha	US$/ha	%	Ratio
1	Coral reefs	542,500	129,200	1,166,000	7%	2,8
2	Coastal	232,700	73,900	935,400	11%	4.4
3	Mangroves	2,880	4,290	86,900	40%	26.4
4	Inland wetlands	33,000	14,200	171,300	12%	5.4
5	Lakes/rivers	4,000	3,800	69,700	27%	15.5
6	Tropical forests	3,450	7,000	148,700	50%	37.3
7	Other forests	2,390	1,620	26,300	20%	10.3
8	Woodland/shrubland	990	1,571	32,180	42%	28.4
9	Grasslands	260	1,010	22,600	79%	75.1

Note: Costs are based on an analysis of appropriate case studies; benefits have been calculated using a benefit transfer approach. The time horizon for the benefit calculation are 40 years (consistent with our scenario analysis horizon to 2050); Discount rate = 1%, and discount rate sensitivity by flexing to 4%, consistent with TEEB 2008). All estimates are based on ongoing analyses for TEEB (see chapter 7 TEEB D0 forthcoming). As the TEEB data base and value-analysis are still under development, this table is for illustrative purposes only.

TEEB preliminary data (not mine!)

Ecological restoration A happy ending?

- Restoration methods are improving & have a scientific basis
- Restoration is supported by policy (AES, UKBAP, REDD)
- Restoration can be used to enhance biodiversity & ecosystem services
- Is it cost effective…?
- Maintenance of existing habitat remains the best policy