Long-term ecosystem research & monitoring: from local to global

Development of the UK Environmental Change Network and its role in addressing current and future environmental issues

Terry PARR
twp@ceh.ac.uk

UK
Centre for Ecology and Hydrology
Natural Environment Research Council

Environmental Change Network

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

The UK Environmental Change Network (ECN)

The UK's long-term ecosystem monitoring and research (LTER) network.

1992-

www.ecn.ac.uk

Cynulliad Cenedlaethol Cymru
The National Assembly for Wales

Countryside Council for Wales

Summary

- **Brief overview of ECN**
  - **Integrated approaches to environmental monitoring and research**
    - **Multi-scale approaches within the UK**
    - **Networking LTER: site- national-continental-global integration**
- **Analysis: ECN in relation to**
  - **Biodiversity and climate change**
  - **Data resources**
- **Knowledge transfer and outreach**
  - **Uses in research, policy and education**

The UK:
Many people, much urbanisation, intensive agriculture, continuing economic growth

landscapes are highly modified by human activities

- Multiple drivers and pressures affect the state of biodiversity
- Multiple stakeholders
- Need to predict and manage environmental change impacts

- Long-term ecosystem research to understand, predict and manage changes
- Inter-disciplinary

Public, policy and media concerns

Ecology » Fish stocks and sea bird numbers plummet as soaring water temperatur

North Sea faces collapse of its ecosystem

By Richard Sadler and Geoffrey Lean

The North Sea is undergoing "ecological meltdown" as a

dence of climate change on a large-scale ecosystem. We are likely to see even greater warming, with temperatures becoming more like those off

their expected rec severe cuts in fish They say that warming will effec of marine life,

Newspaper of the Year

THE INDEPENDENT

No 5,709 www.independent.co.uk MONDAY 24 JANUARY 2005 (Republic of Ireland €0.95) 60p

Climate change: report warns point of no return may be reached in 10 years, leading to droughts, agricultural failure and water shortages

Countdown to global catastrophe

55p Friday March 19 2004 Published in London and Manchester guardian.co.uk

The Guardian

The decline of species ...

British study covering last 40 years points to worldwide mass extinction of wildlife and plants

Tim Radford Science editor

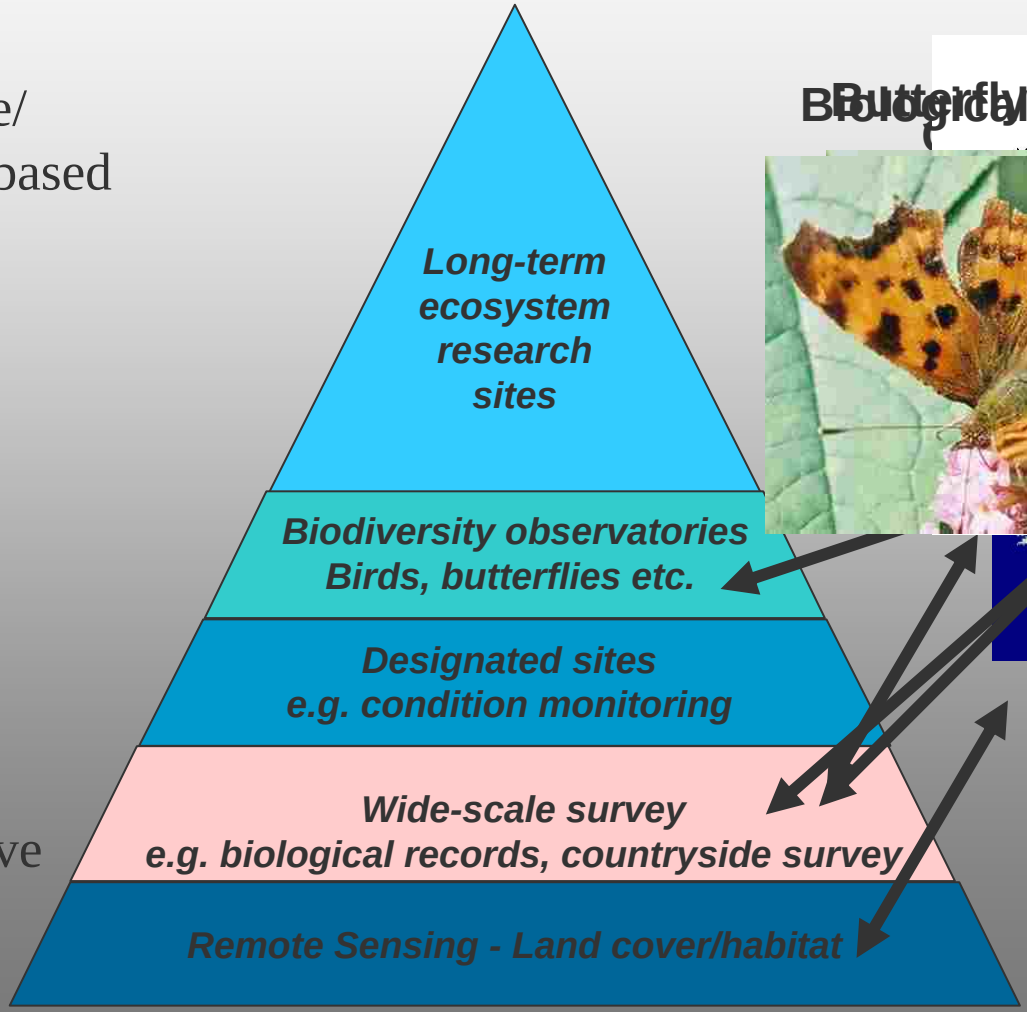
Disaster at sea: global warming hits UK birds

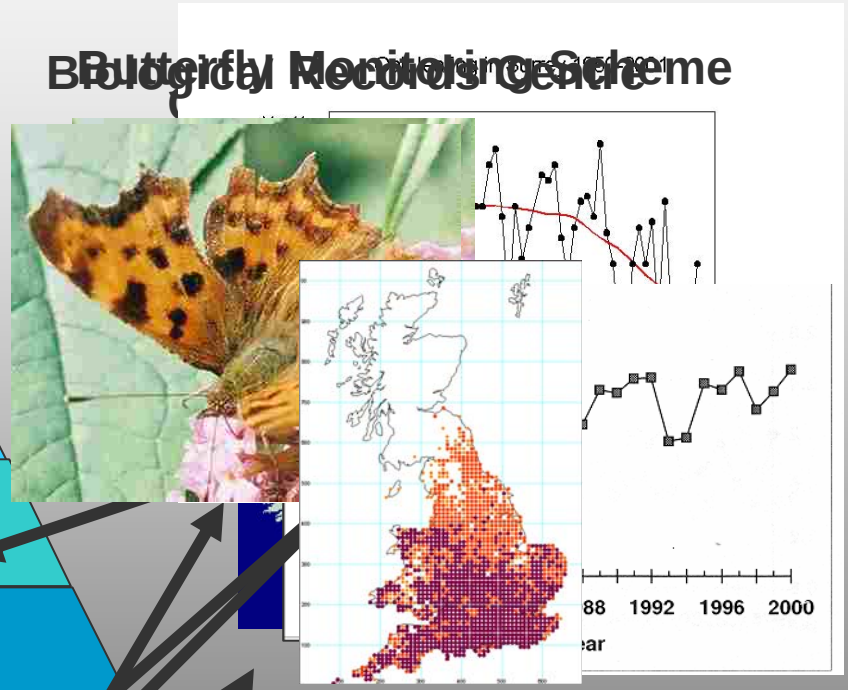
By Michael McCarthy Environment Editor

UK Observation and Research Hierarchy for ecosystem research

Intensive/
process based

Extensive
survey





Land Cover Map 1990, 2000, 2007

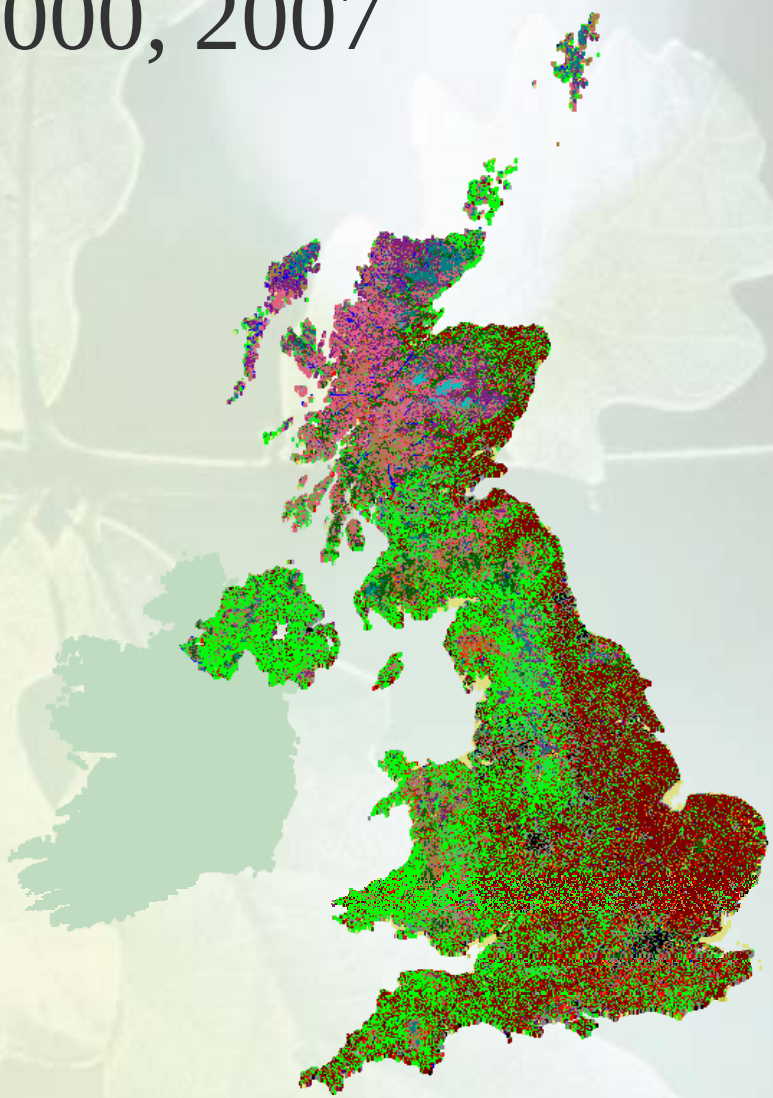
Comprehensive UK coverage

Vector data set containing 6.6 million land parcels (segments)

0.5 ha minimum mappable unit

Widespread Broad Habitats

Landsat



Uses of Land Cover Map data

Atmosphere & climate change

Water & catchments

Marine & coastal

Ecology & conservation

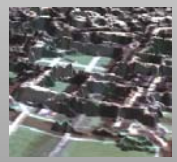
Impact assessment

Health & hazards

Agriculture

Landscape planning

Telecommunications



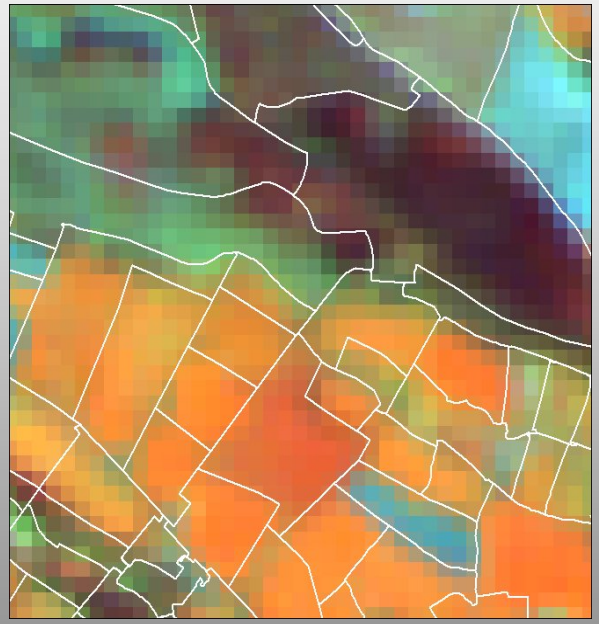
Urban studies

Statistics, information

Education & publicity

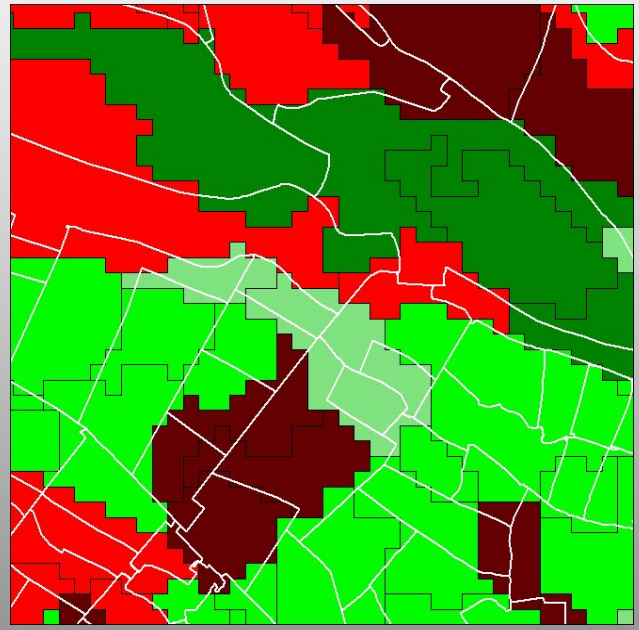
Changing methods

1990



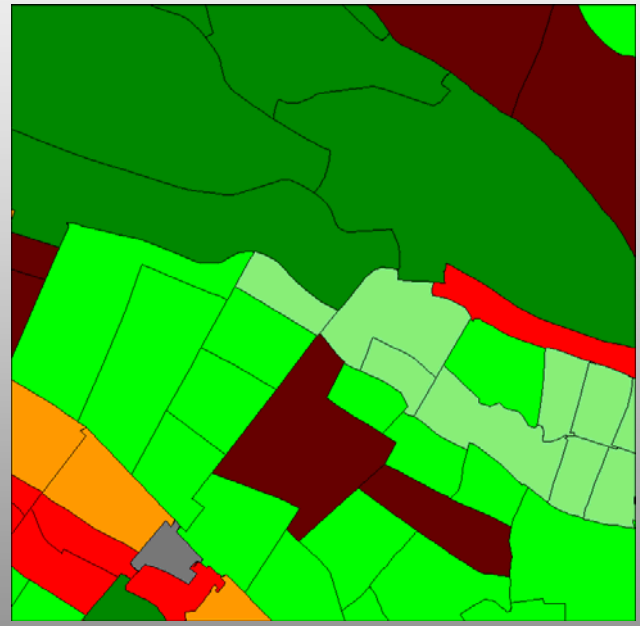
Satellite image & generalised MM

2000



LCM2000 & generalised MM

2007

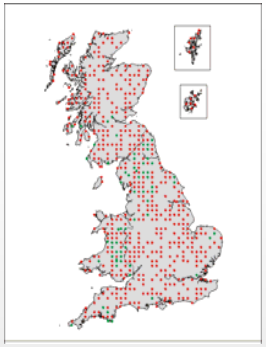


Classified generalised MM (LCM2007)

Ordnance Survey®

Laser-Scan

Countryside Survey



Countryside Survey

Science & Policy

Land Cover Map

Census of land cover using remotely-sensed satellite data

ITE Land Classification

Sample-based field surveys of the UK

Vegetation, habitats, soils, freshwater

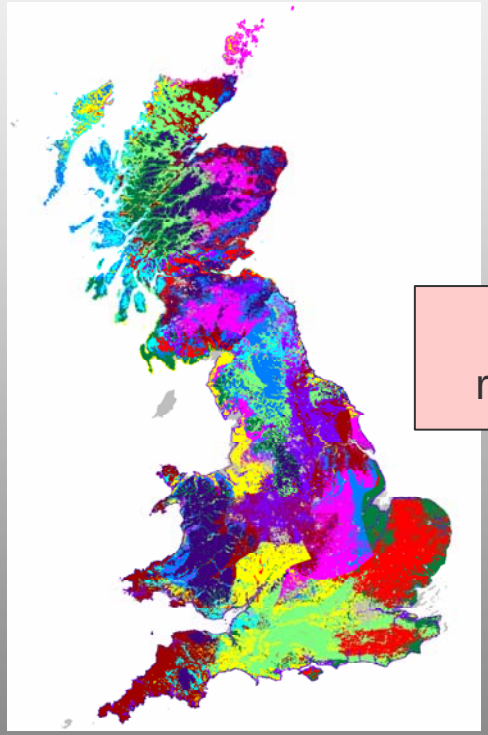
Informatics and Knowledge Transfer

Resource assessment and management in the UK

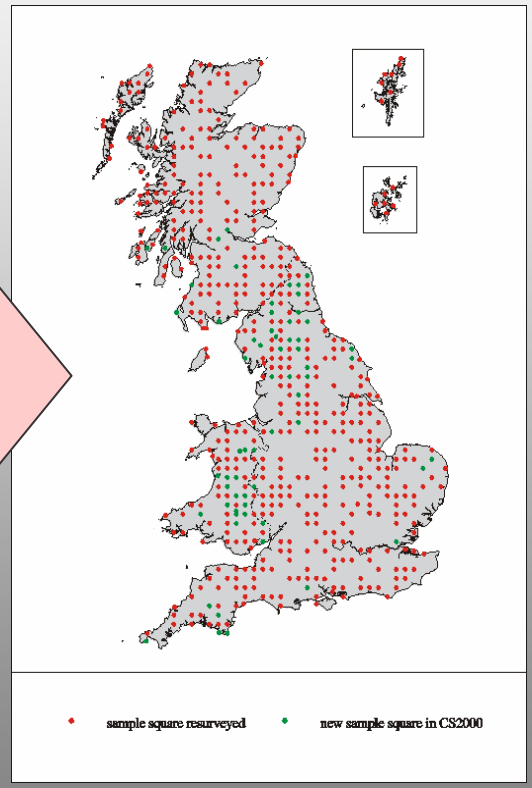
Countryside Survey:
field survey sampling strategy

www.cs2000.org.uk

32 environmental strata



stratified
random sample

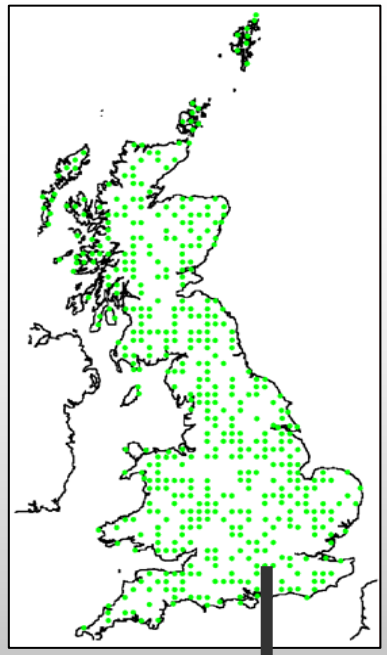


Sample size (km squares)

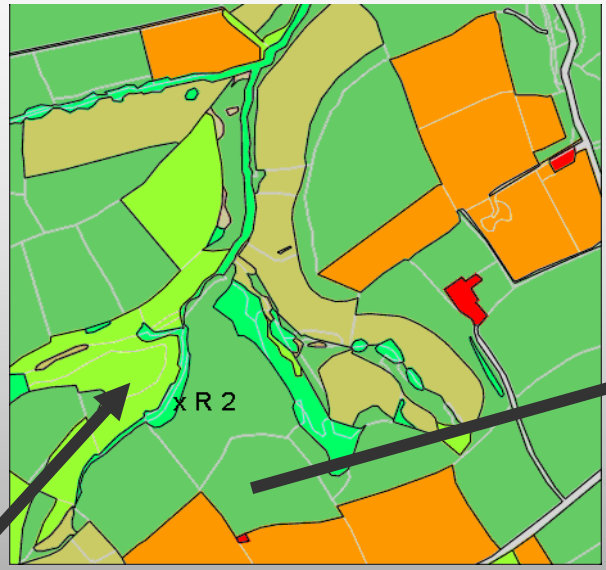
1978 256
1984 384
1990 508
1998 569
2007 629

Based on OS data, climate, soils and geology classified to give 32 land classes

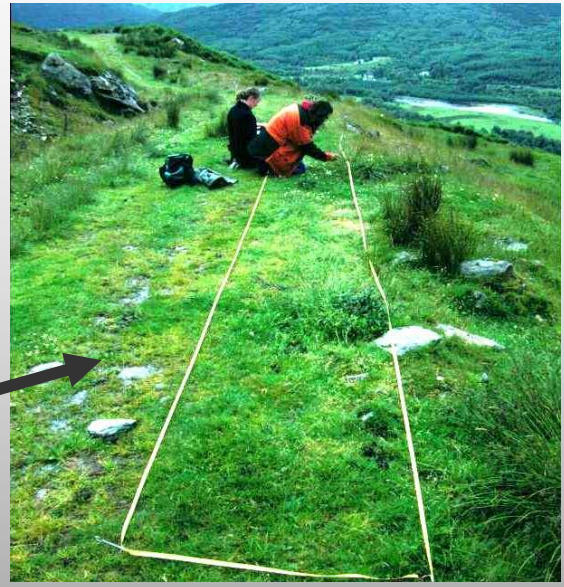
Components of the field survey



GB covered by **629** 1km squares

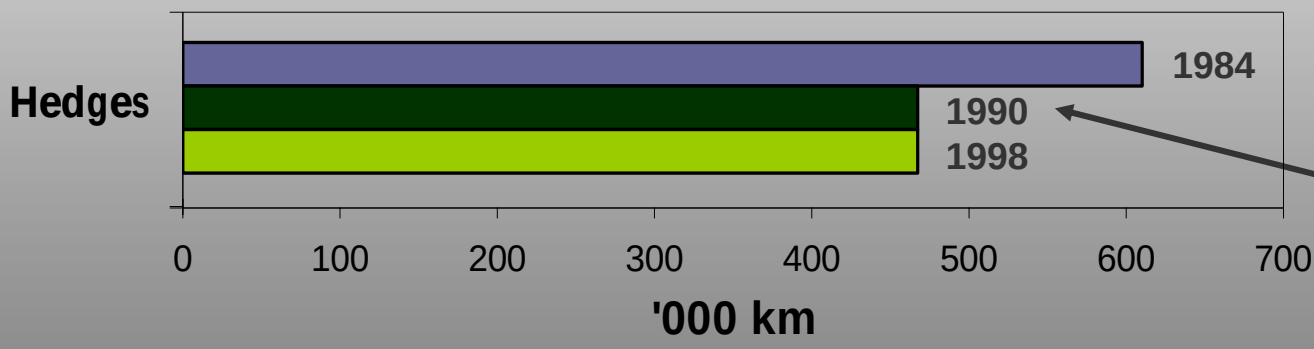


Broad Habitat types and landscape features mapped in each 1km sample square



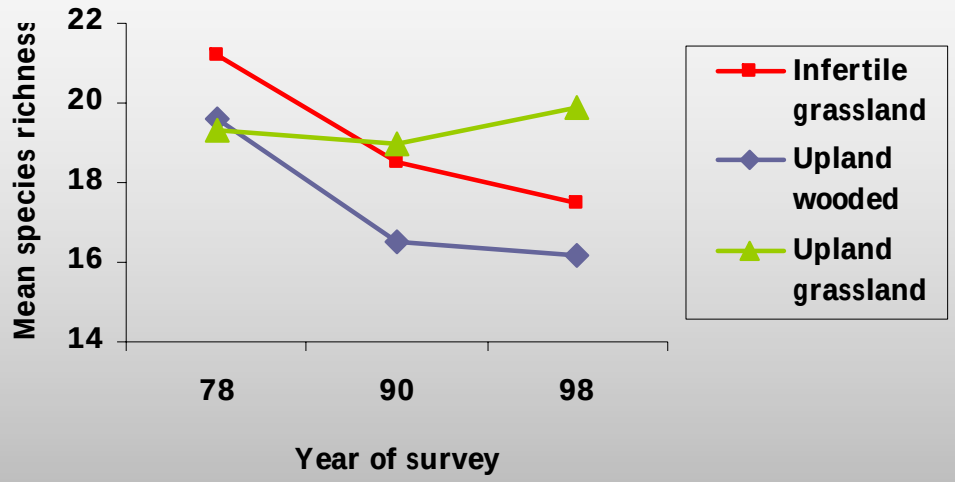
Sampling of
- vegetation (approx 18,000 plots)
- freshwater biota
- soils

Policy - Hedgerow Protection



HEDGEROW PROTECTION LEGISLATION

Changes in Habitat quality



- Evidence that the condition of habitats declined since 1990

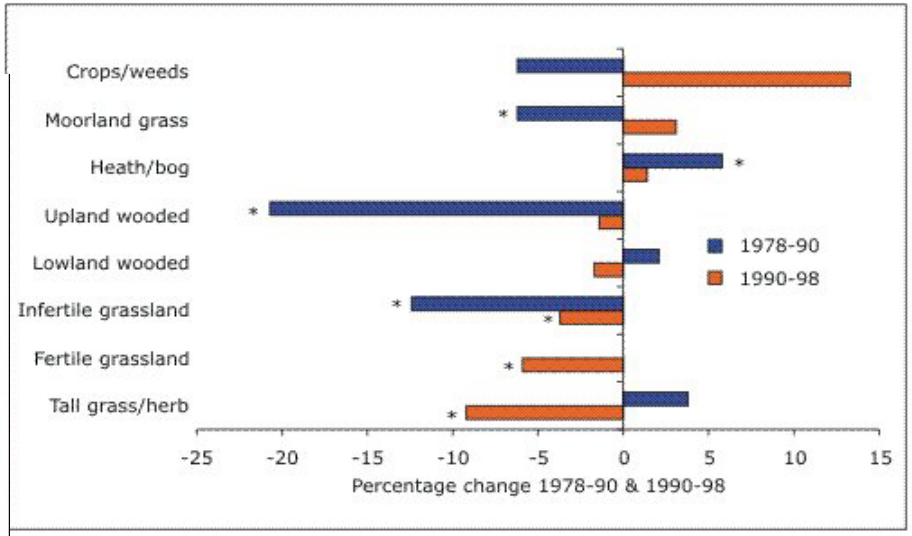
- GB vegetation is becoming more homogenous

Smart *et al. (2006)* Biodiversity loss and biotic homogenisation. *Proc R Soc*

State of the Environment
UK Sustainable Development Indicators

Indicator: Trends in plant diversity

Changes in mean species numbers within major vegetation groups: 1978 to 1998



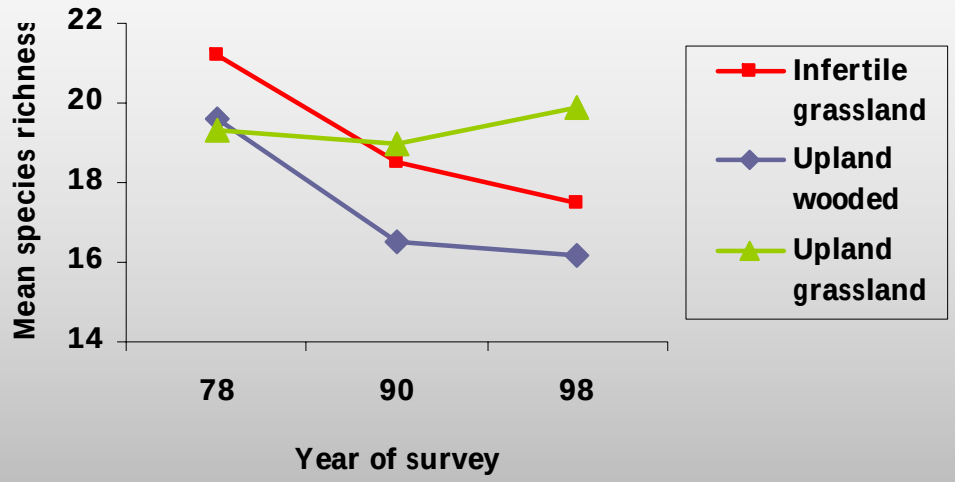
ally significant changes

se the decline in UK wildlife and habitats

CS Research Agenda…

- What has changed?
  - ..SIGNAL DETECTION
- What caused the change?
  - ..SIGNAL ATTRIBUTION
- Do the changes matter?
  - ..UNDERSTANDING CONSEQUENCES FOR ECOSYSTEM SERVICES
- Forecasting and managing change?
  - ..UNDERSTANDING PROCESSES

Changes in Habitat quality



- Evidence that the condition of habitats declined since 1990

- GB vegetation is becoming more homogenous

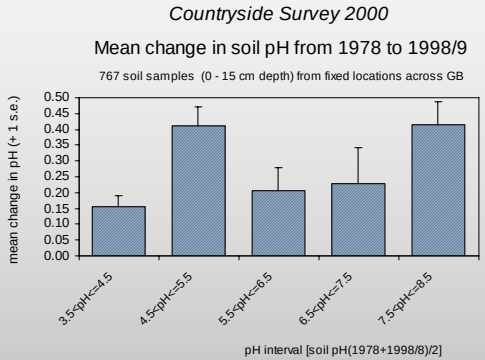
Smart *et al. (2006)* Biodiversity loss and biotic homogenisation. *Proc R Soc*

Key questions - soils
(and measurements)

- **Is soil carbon changing and what are the drivers**
  - *LOI, organic C*
- **Is recovery from acidification continuing?**
  - *pH*
- **Is eutrophication continuing?**
  - *%N and available-N*
- **What are the links between changes in below-ground biodiversity and changes in C and N?**
  - *Invertebrate diversity, C, N*
- **Are their good indicators of soil quality and health?**
  - *Olsen P, available N, LOI, invertebrate diversity, metals*

Changing states - soils

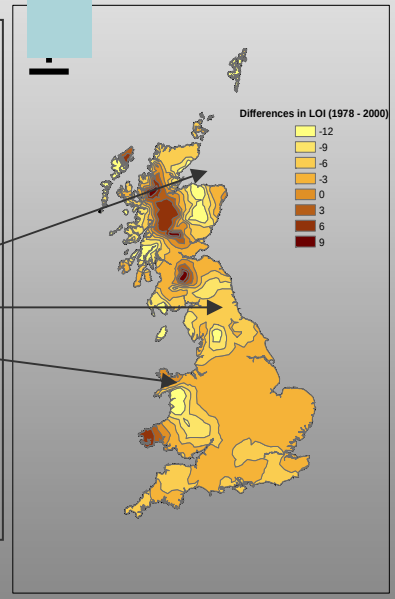
Clear evidence of recovery from acidification



Black et al., 2003. J. Env. Manag.

National map of change in soil organic matter content

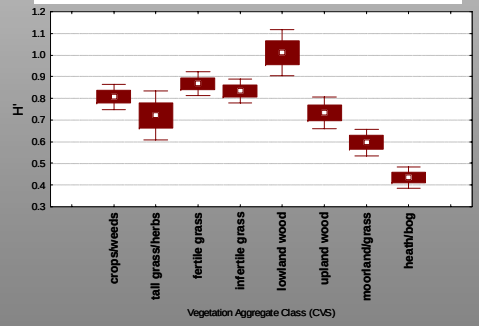
NB: Suggest Soil carbon is increasing in some areas. Differs from Bellamy 2005 Nature paper



Black, Frogbrook et al., In Prep

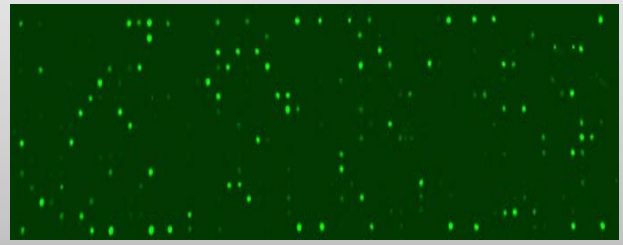
1998

First ever national survey of invertebrate diversity



New Methods for Looking at Change
CS2007 and Molecular Ecology

Soil cores:



Use of molecular techniques e.g. high density “microarray technologies” to assess multiple taxa and relationships to ‘soil quality’

- **first country-level survey of microbial diversity in terrestrial ecosystems**
- establish baseline measurements for future surveys
- UK wide genomic archive of our microbial biodiversity

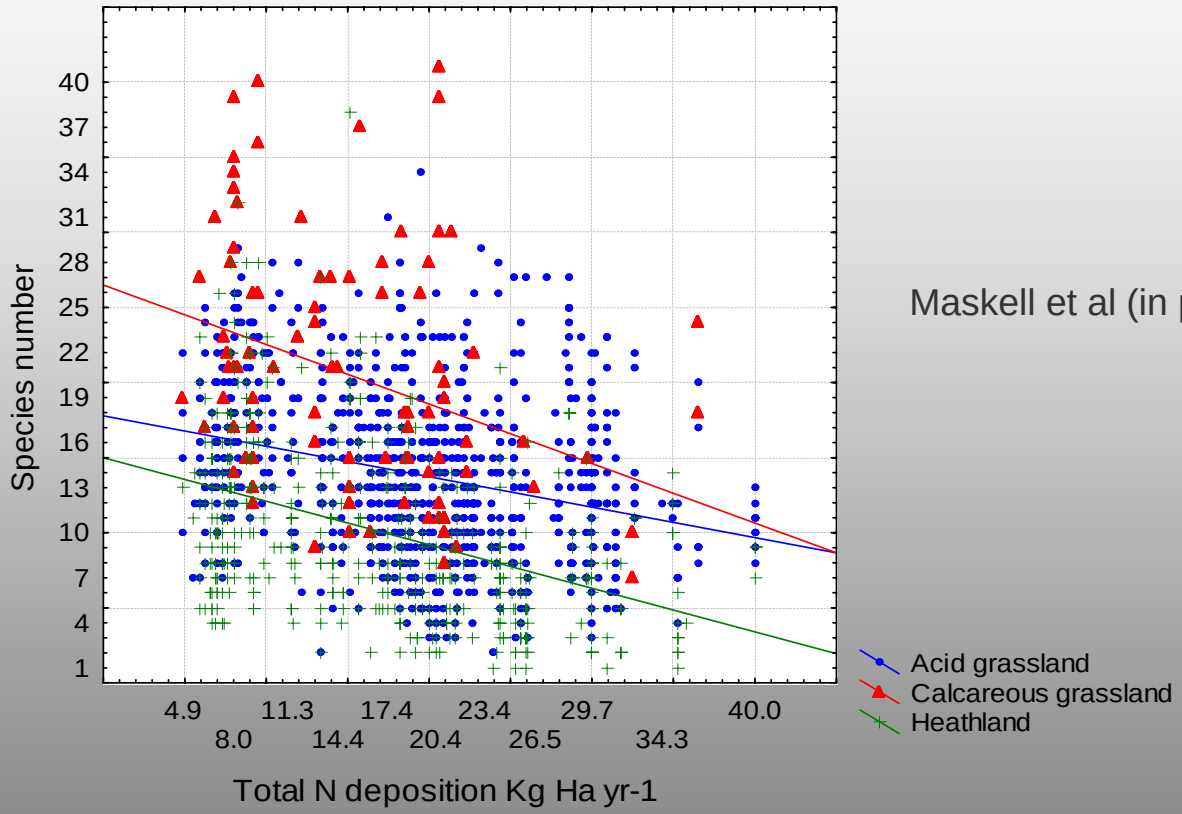
CS Research Agenda...(2)

- What caused the change?

  ..SIGNAL ATTRIBUTION

  - Land use change – agriculture & forestry
  - Atmospheric pollution
  - Non-native species
  - urbanisation
  - Climate change

Are nitrogen inputs from the atmosphere a major driver of GB vegetation change?



Maskell et al (in prep)

2003 Smart *et al* Locating eutrophication effects in vegetation *Global Change Biol* **9** 1763

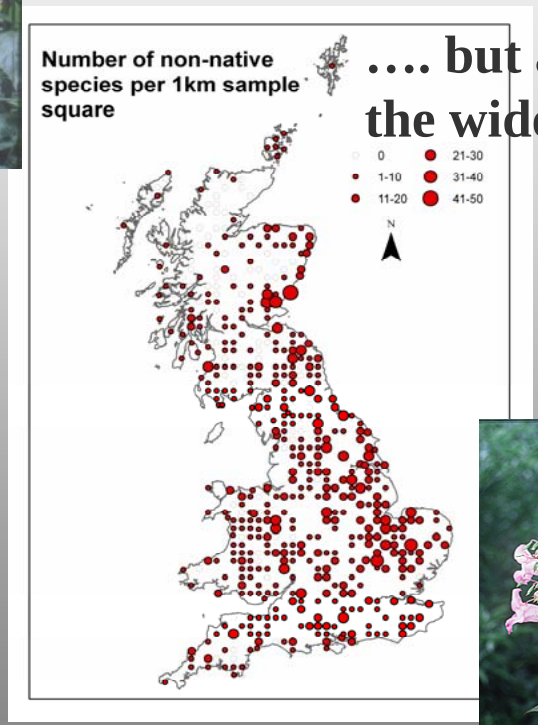
2004 Smart & Scott. Bias in use of Ellenberg N. *J Veg Sci* **15** 843

2004 Smart *et al* Detecting signal of atmospheric deposition of N on vegetation change *Water, Air and Soil Pollution* **4** 269

Are non-native species a problem?

Japanese knotweed is not significant in CS

Non-native species often have a big local impact …



…. but are not yet a big problem in the wider countryside.

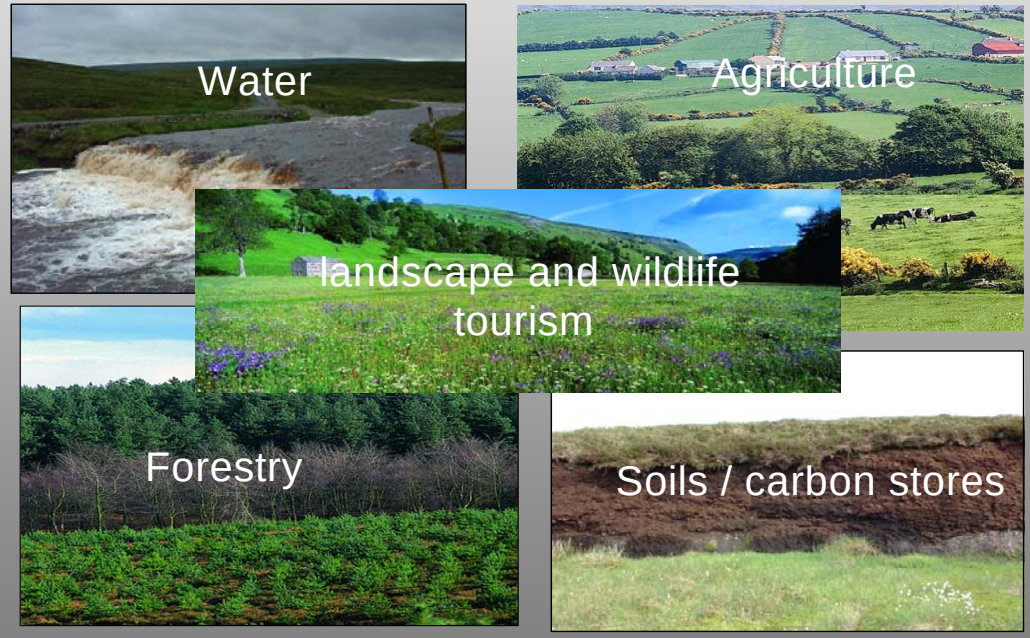
Himalyan balsam only present in 30 plots in 1998

Maskell *et al* (2006) Non-native plants in common habitats. *J Ecol*

CS Research Agenda...(3)

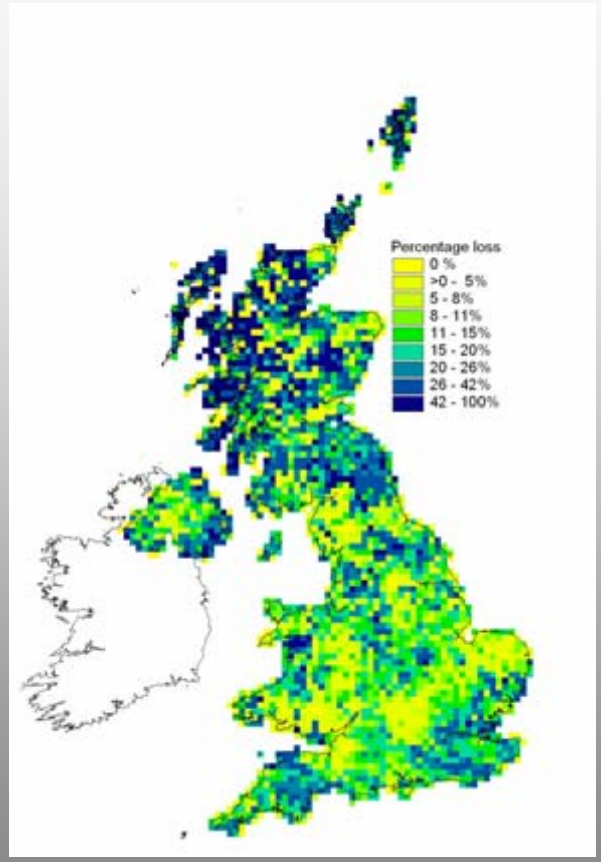
- Do the changes matter?

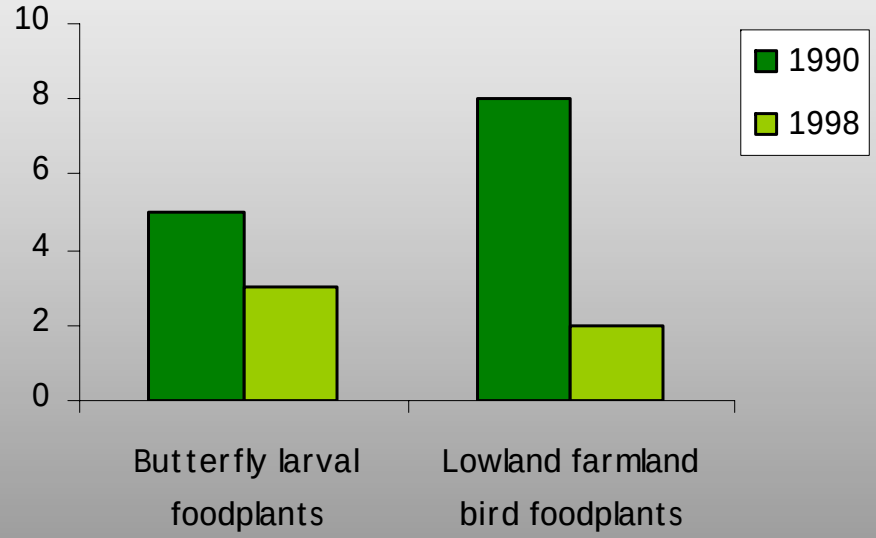
  ..UNDERSTANDING CONSEQUENCES FOR ECOSYSTEM SERVICES



Loss of Biodiversity

Declines in arable weeds



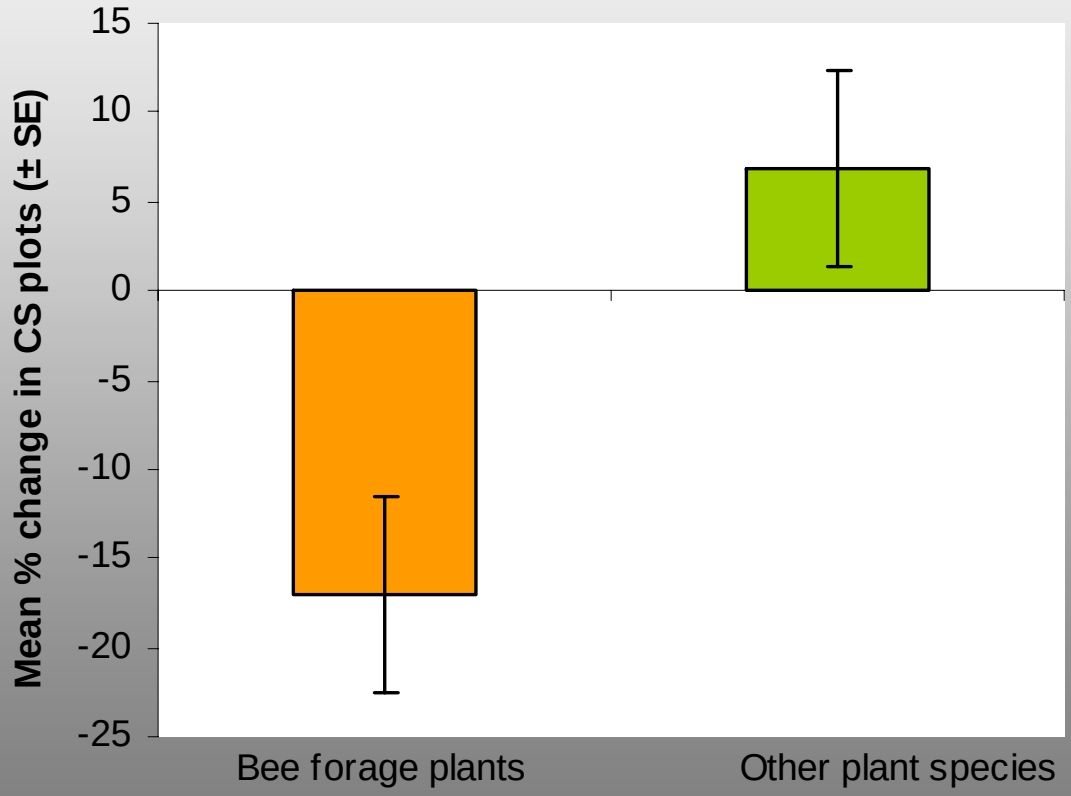


Declines in butterfly and bird foodplants

Smart *et al* (2000) Changes in abundance in food plants for birds and butterflies *J Appl Ecol* **37** 398

Loss of Pollinators

Decline of bumblebee forage plants 1978-1998



COUNTRYSIDE SURVEY2000

Carvell et al. (2006) Biol. Conservation

Sustainable Land Management Research and Advice

- Prescriptions for sustainable rural land management under agricultural reform

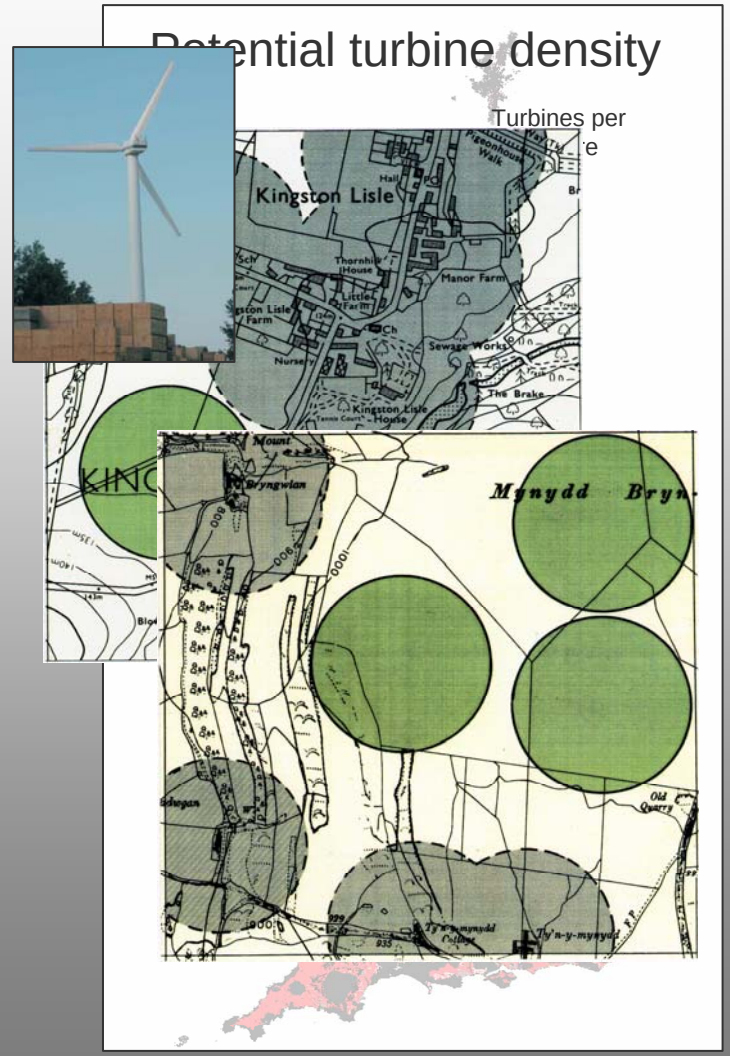
- Catchment management

- Capacity for renewable energy production

CS & Energy Issues

Environmental capacity to provide energy

- CS provides info for:
  - Carbon inventory
  - Wood energy
  - Novel biofuels
  - Wind turbines
  - Critical loads
  - Natural stock at risk



UKERC

UK ENERGY RESEARCH CENTRE

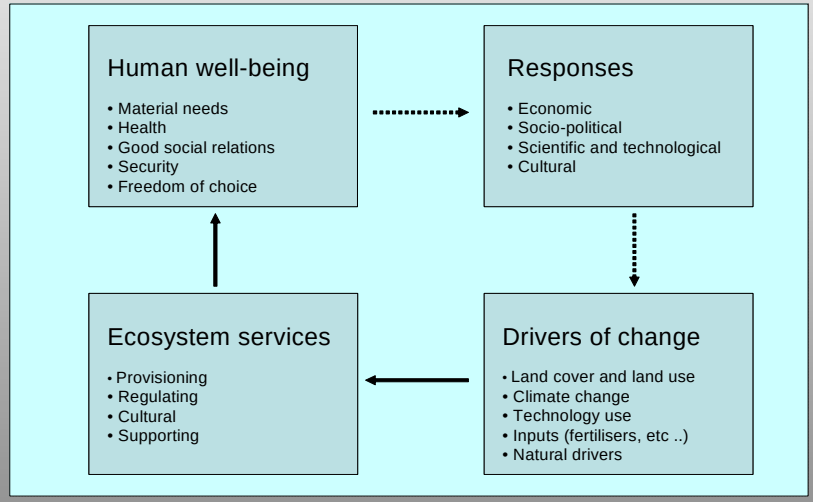
CS Research Agenda...(4)

- Forecasting and managing change?

  ..UNDERSTANDING PROCESSES

Integrated assessment framework

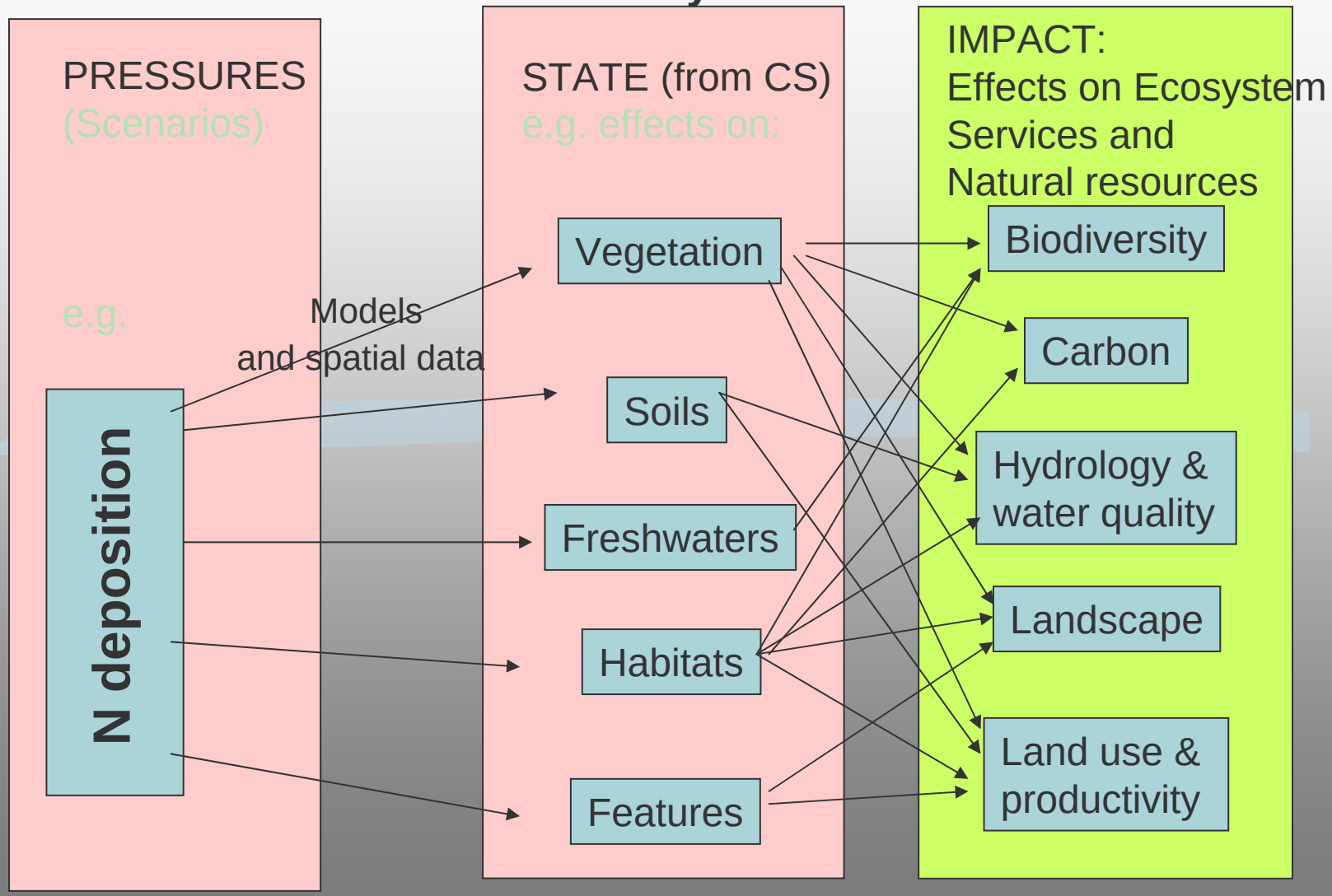
Millennium Ecosystem Assessment (2003):



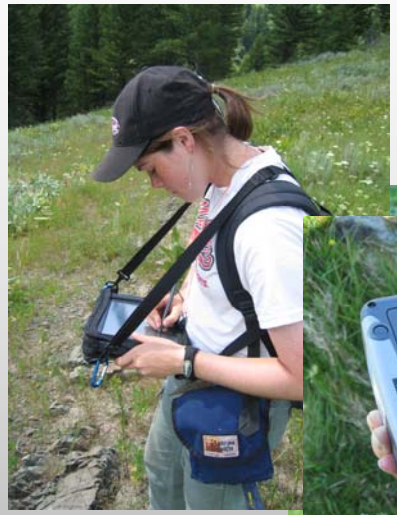
How will ecological impacts of different pressures translate into effects on ecosystem services?

CS & Natural Resource Management

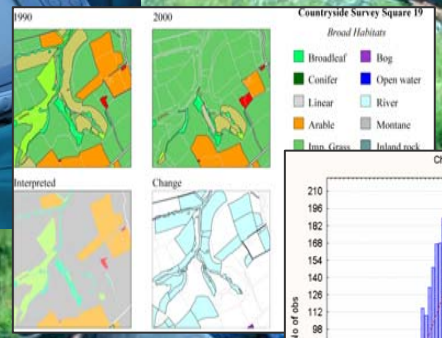
How will ecological impacts of different pressures translate into effects on ecosystem services?

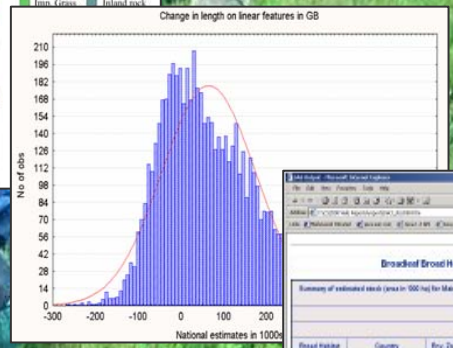


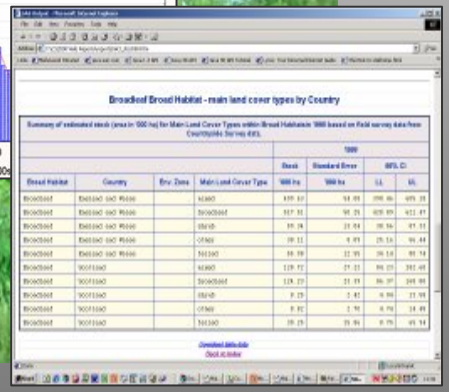
Countryside Survey 2007 - Informatics



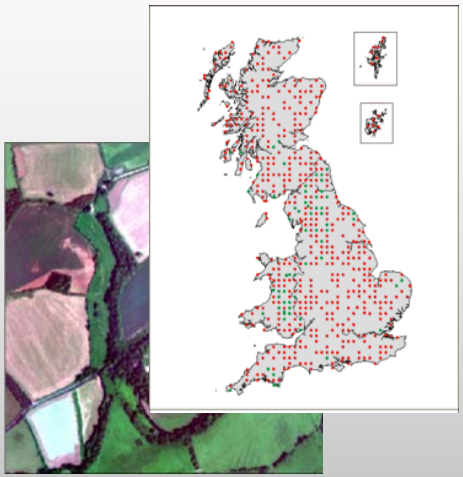
.. data brought together to deliver robust information - quickly.







CS 2007 - Conclusion



STRENGTHS

- **Large-scale, long-term policy relevant survey**
  - cross-sectoral policy development
  - links field and remote sensing data
- **Science outputs and potential**
  - major trends and pressures in the countryside
  - implications for key ecosystem services

WEAKNESSES

Expensive

Causes of change at ecosystem level

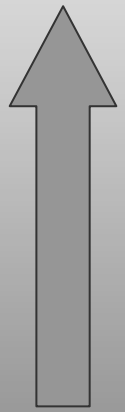
- e.g climate change

Forecasting

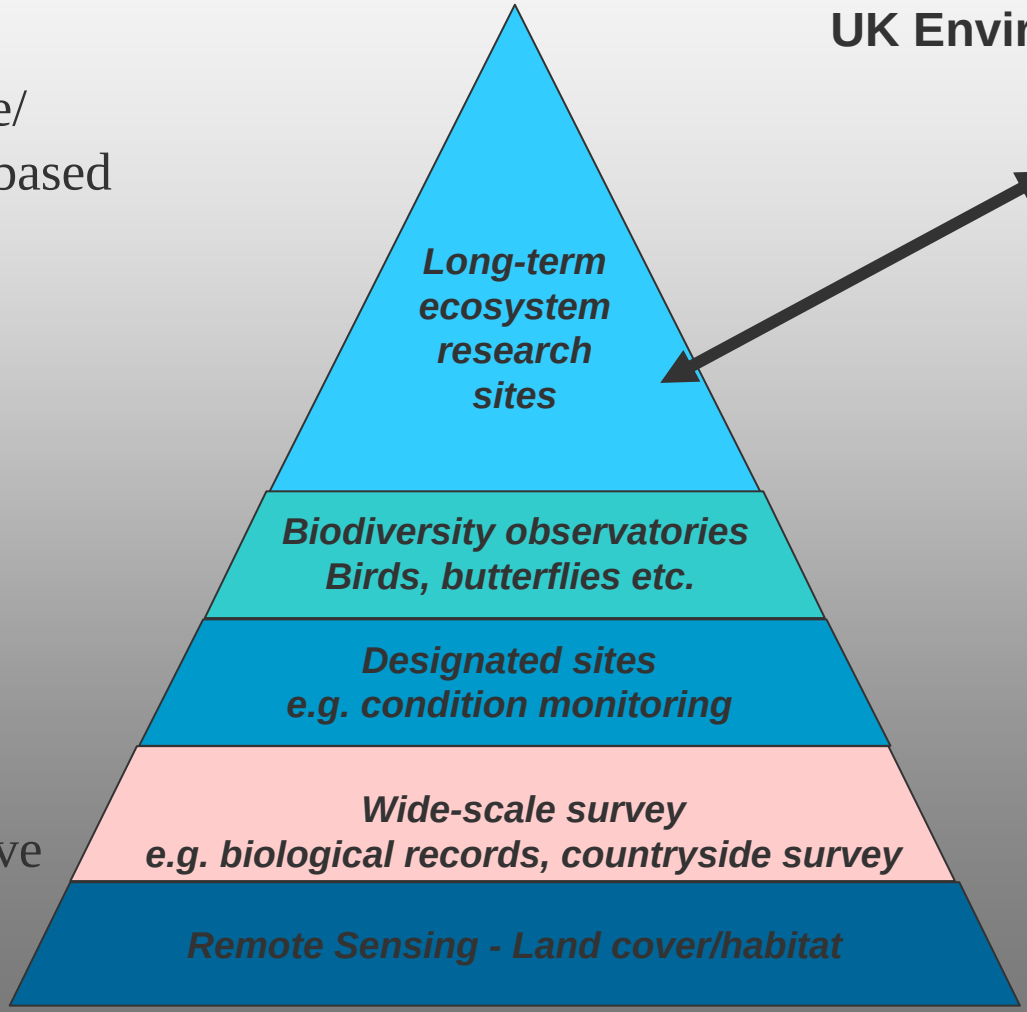
- e.g future climate change impacts

UK Observation and Research Hierarchy for ecosystem research

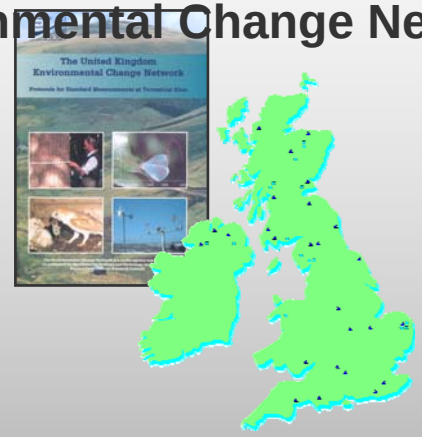
Intensive/
process based



Extensive
survey



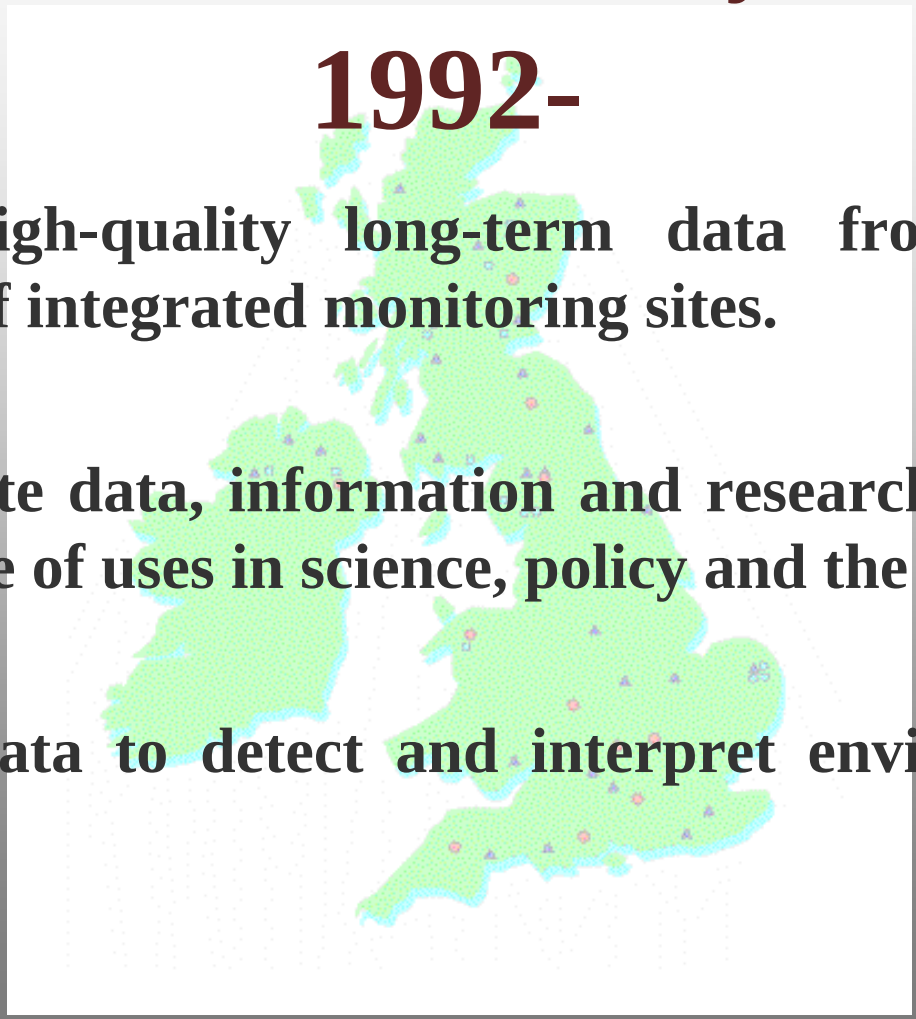
UK Environmental Change Network



UK Environmental Change Network

Rationale and Mission Objectives

1992-



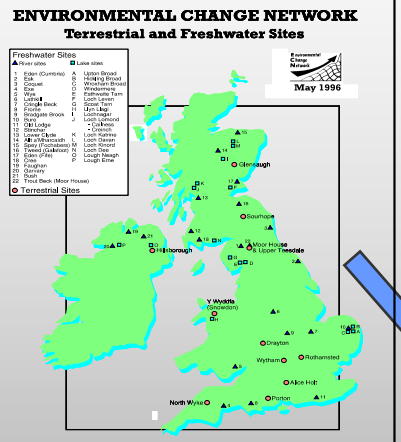
- **Collect high-quality long-term data from a UK network of integrated monitoring sites.**
- **Disseminate data, information and research products for a range of uses in science, policy and the public.**
- **Analyse data to detect and interpret environmental change.**

The UK Environmental Change Network

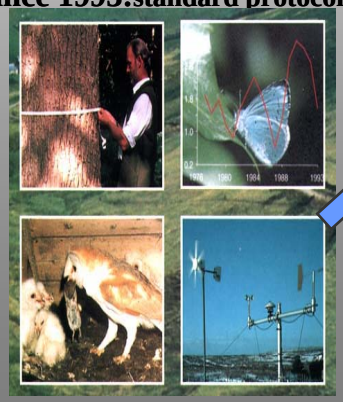
Monitoring and research to detect and interpret environmental change

14 sponsoring and 9 research organisations

54 SITES



260 MEASUREMENTS
driver and response variables since 1993:standard protocols



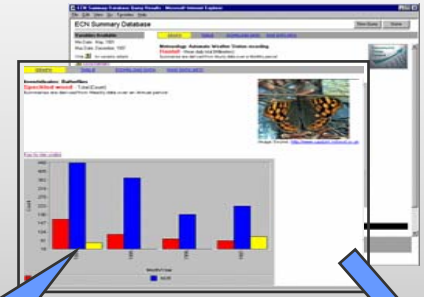
+

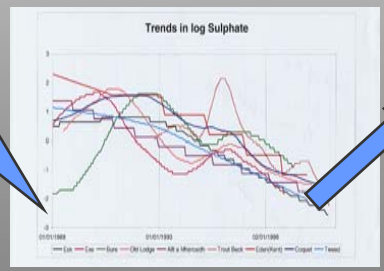
long-term experiments and process studies

CENTRAL DATABASE
www.ecn.ac.uk

Quality Assurance:
- ***Control***
- ***Validation***
- ***Assessment***

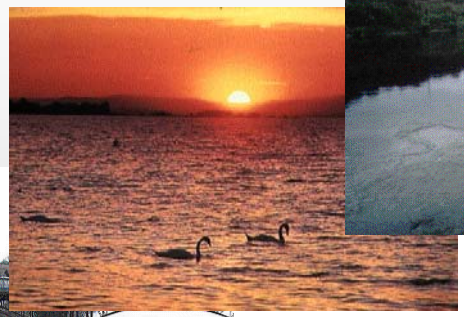
External use:
Direct Web-to-database access for users in science, society and education





Internal Use:
Analysis & Modelling for:
-indicators
-trend detection
- forecasting

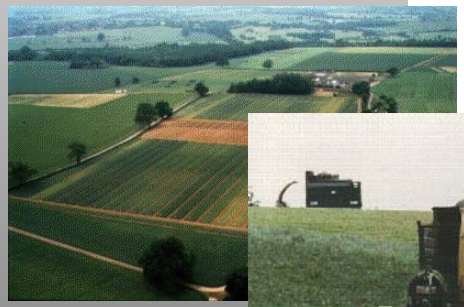
ISSUES
Climate change
Atmospheric pollution
Land-use change
Water resources
Biodiversity
Soil quality

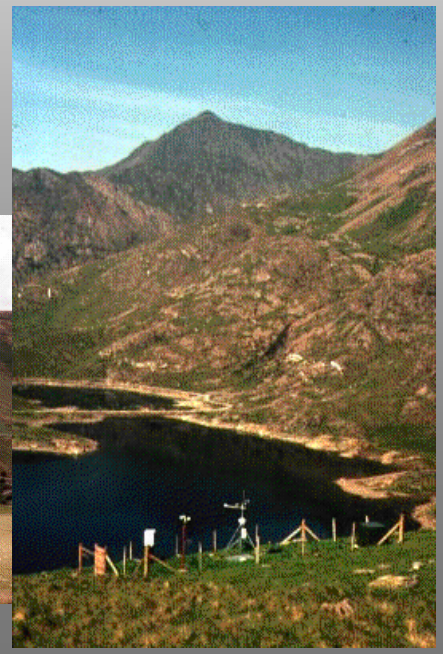

42 ECN Freshwater Sites

Disturbed Sites < ---------- >Near Pristine Sites

12 ECN Terrestrial Sites



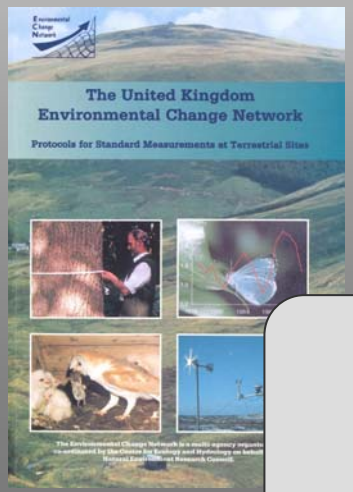




Integrated measurements of pressures, states and ecosystem services

Terrestrial Protocols

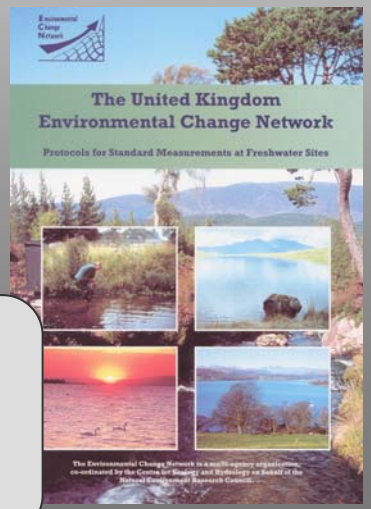
- Meteorology
- Atmospheric Chemistry
- Surface water flow & chemistry
- Soil solution chemistry
- Precipitation chemistry
- Soil surveys



- Vegetation surveys
- Vertebrates (birds, rabbits, deer, bats, frogs)
- Invertebrates (butterflies, moths,

Freshwater Protocols

- Surface water chemistry
- River discharge
- Continuous pH, temperature, conductivity & turbidity
- Temperature and dissolved oxygen profiles for lakes
- Chlorophyll *a*
- Invertebrates
- Macrophytes
- Zooplankton
- Phytoplankton

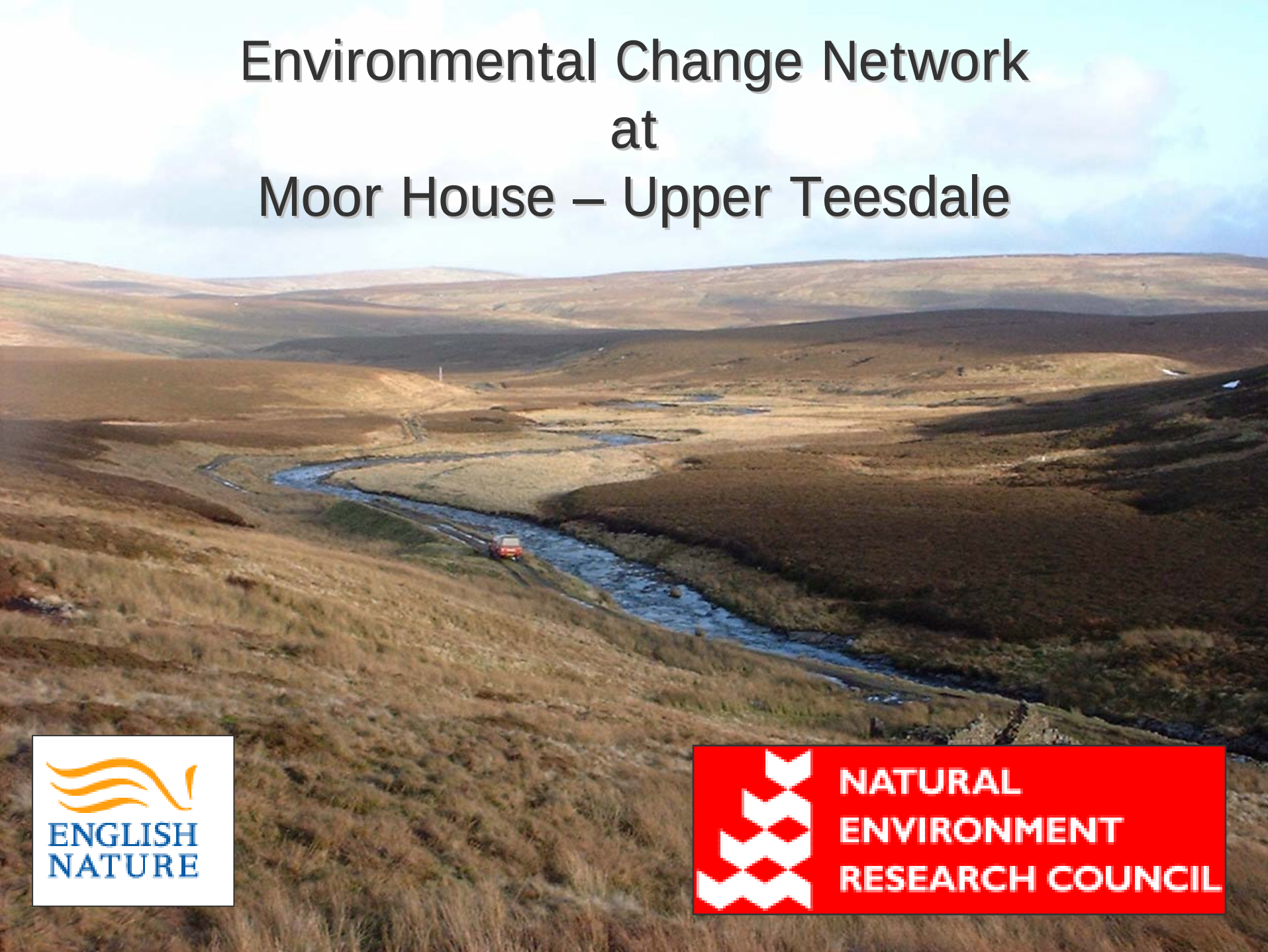


Linking the cause and effects of environmental change

Detecting and attributing change

The value of ECN/LTER Sites

Environmental Change Network
at
Moor House – Upper Teesdale

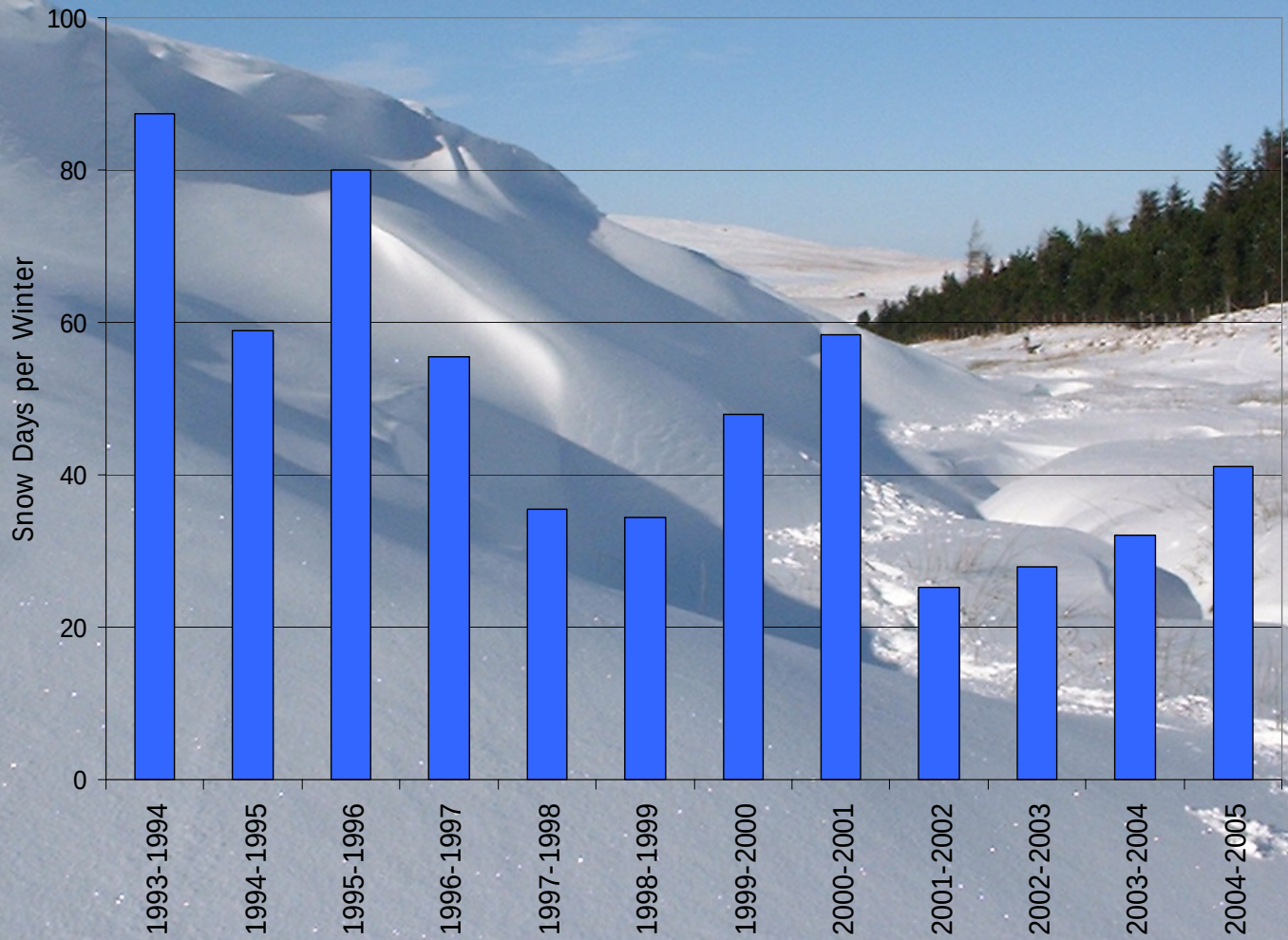


ENGLISH NATURE

NATURAL ENVIRONMENT RESEARCH COUNCIL

Climate warming - “Snow Days”

ECN Moor House



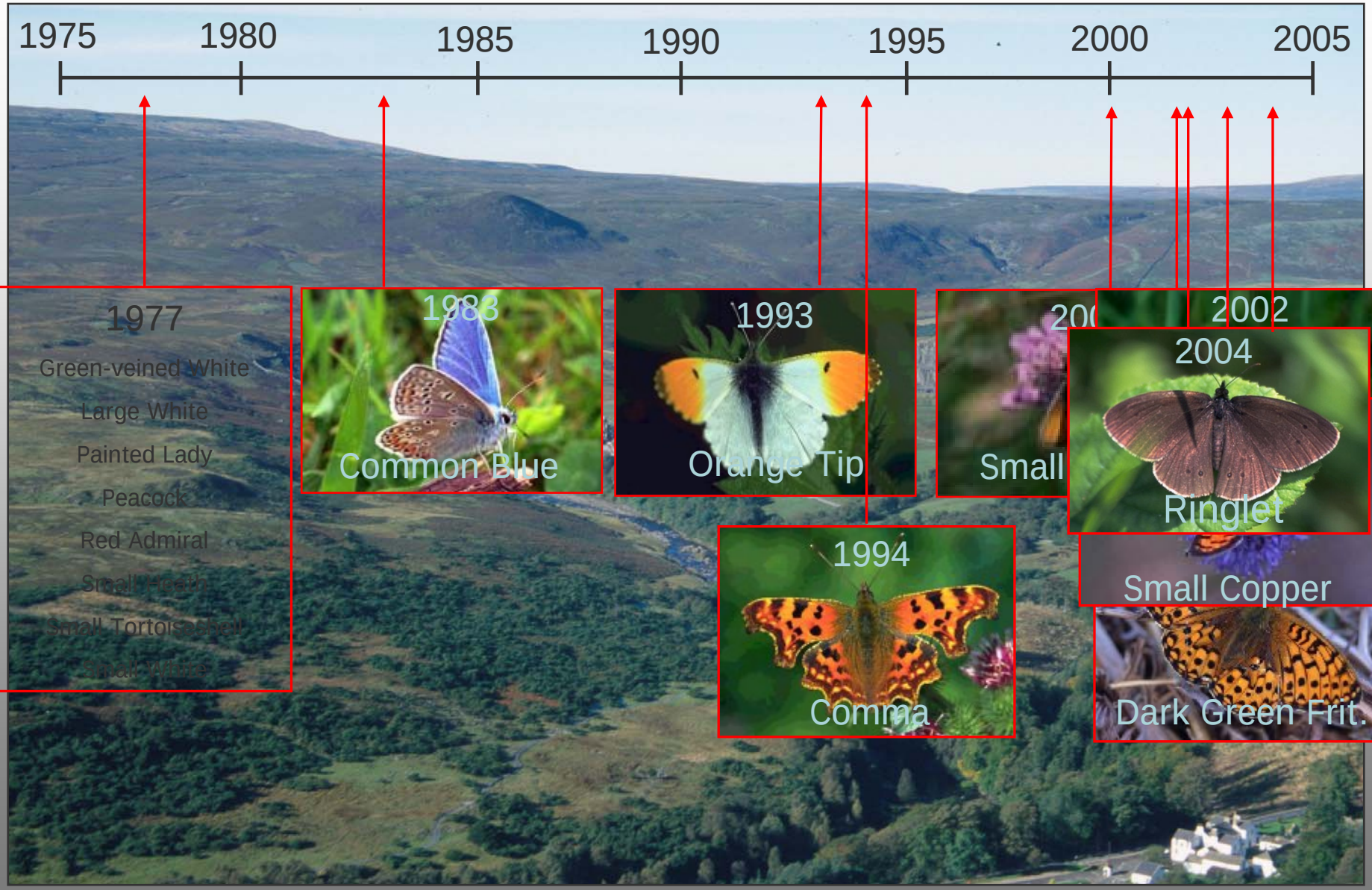
ECN Data

Climate effects

Frog Spawning at Moor House

ECN Data

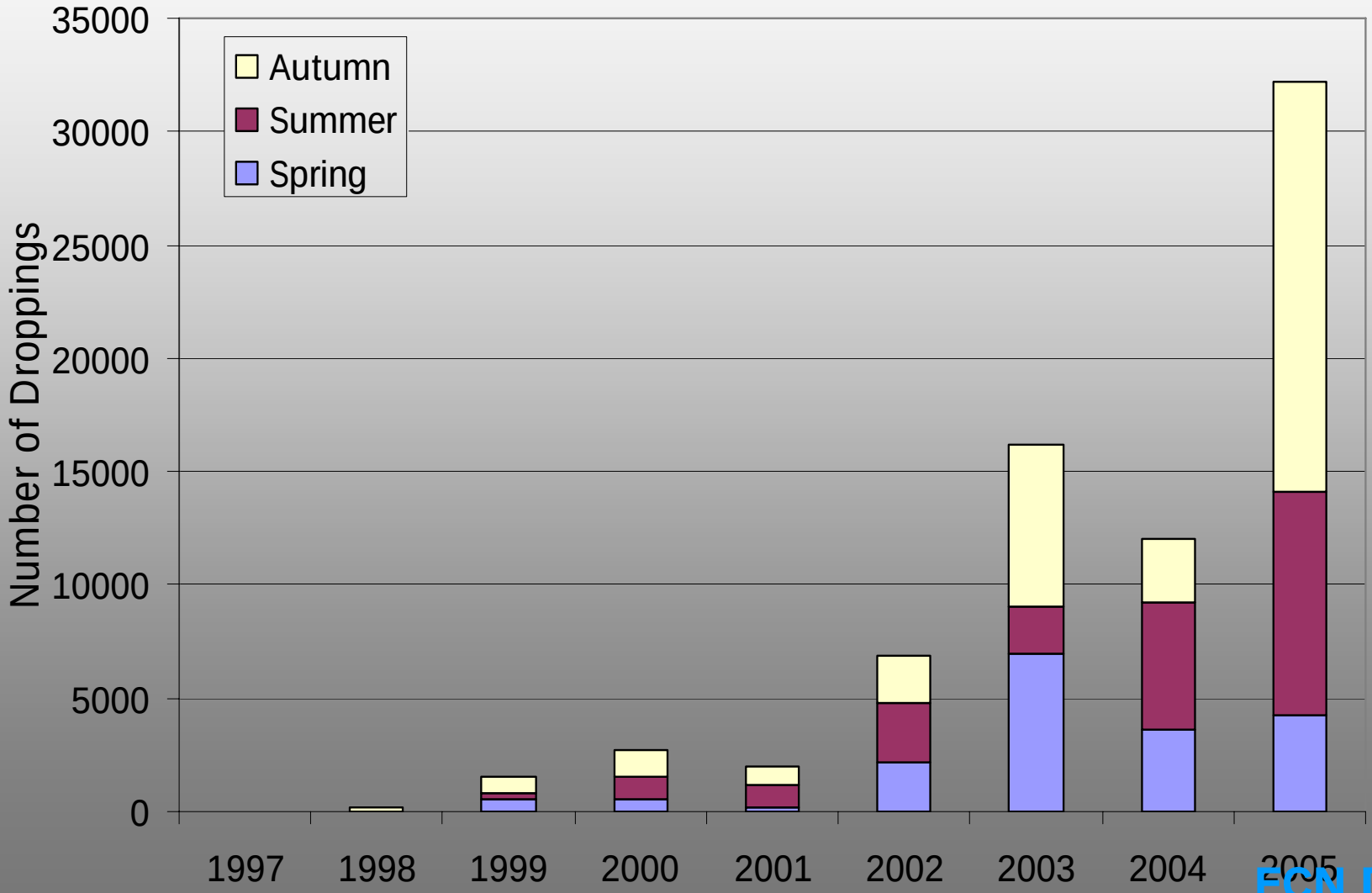
Climate Effects? - Butterflies



ECN Data from Ian Findlay, Butterfly Photos www.butterfly-guide.co.uk

Grazing

Rabbit Density at Moor House



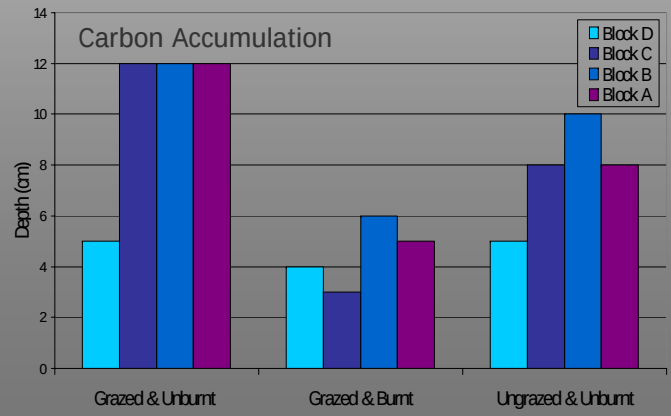
ECN Data

Experiments

Grazing Removal Plots, 1954 to 2001

Burning Plots, Established 1954

Carbon Dynamics and Moor Burning



Garnett, Ineson & Stevenson (2000) The Holocene, 10, 729 - 736

ECN Moor House:

Multi-functional multi-partner research platform

Organisations Working at Moor House in 2005

Glasgow University

CEH Edinburgh

Moor House
Upper Teesdale

Durham University
(Biology, Geog & Earth Sci)

CEH Lancaster
Lancaster University
(Env Sci & Biology)

York University

Leeds University

Manchester University

University of
Wales

CEH Wallingford

Reading University

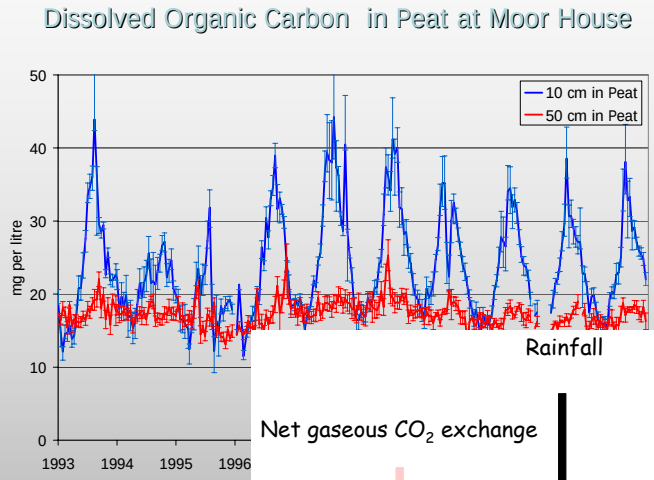
Portsmouth University

Main Research Areas Since 1996

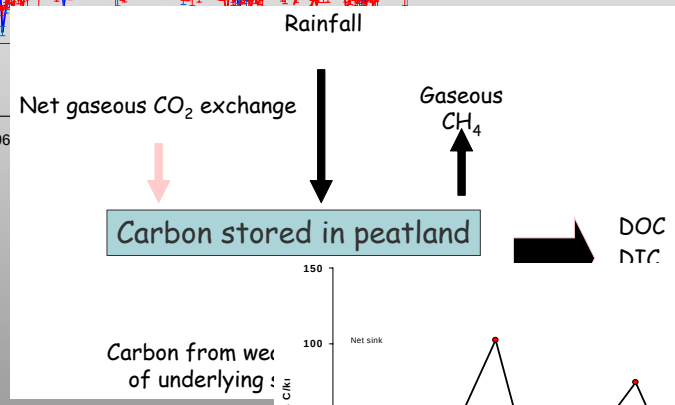
Peatland carbon dynamics
Effects of land management
Stream sediment dynamics
Biogeochemisty
Peat erosion
Peatland hydrology
Pollution deposition
Upland meteorology
Autecology (eg Red Grouse, Northern Eggar)
Population dynamics (eg stream inverts)
Impacts of altitude (eg spittle bugs)

Ecosystem Services - Climate Change Mitigation

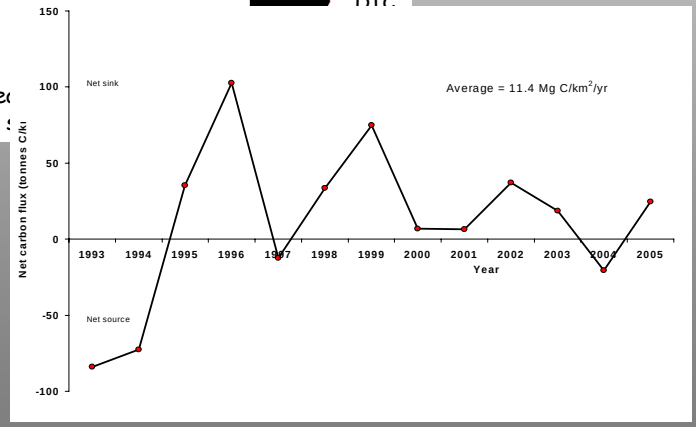
Are UK upland peats a sink or source of carbon?



ECN Data – e.g. dissolved organic carbon

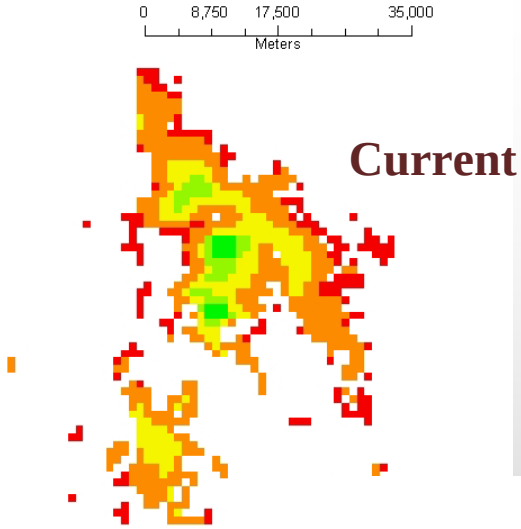


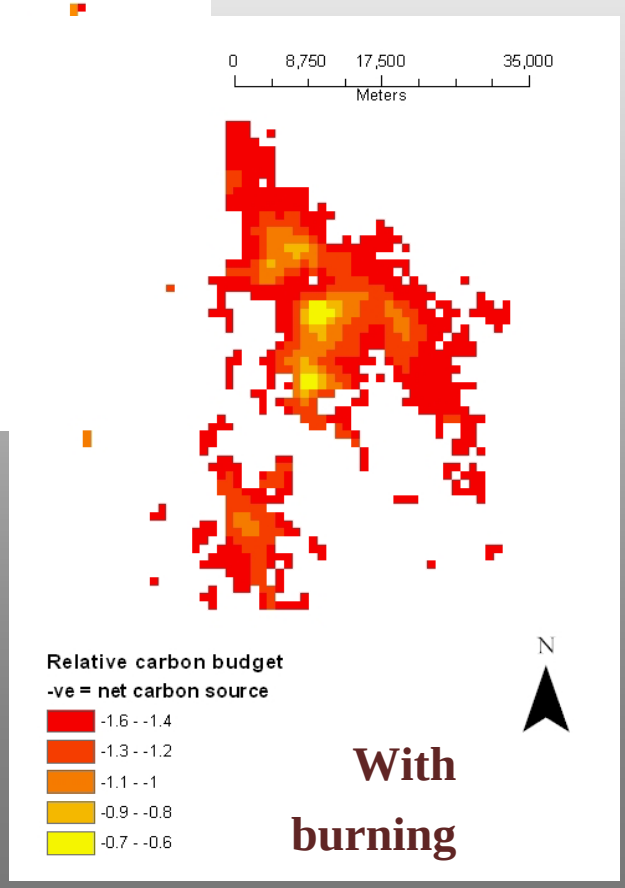
Used to construct carbon budgets and models



Indicate peats may be changing from C-sink to source

Sustainable Uplands





- What is the future of carbon storage in the uplands?
- What management strategies can we use to enhance carbon storage?
- Using models developed and calibrated at Moor House and applying them to Peak District National Park

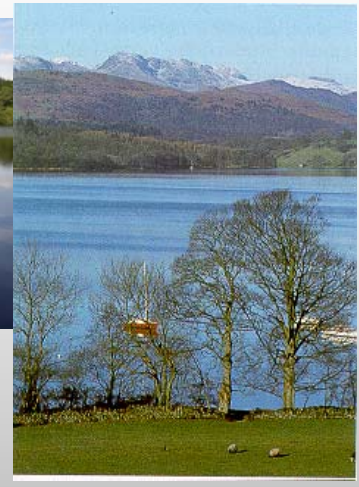
Detecting and attributing change

The value of UK Networks

Long-term changes in lake ecosystems: trends, causes & consequences

Lake Ecosystem Group
Centre for Ecology & Hydrology
Lancaster Environment Centre
E-mail: scm@ceh.ac.uk

Long-term data on lakes in Cumbria



Over 300 lake-years of data: at least fortnightly (previously weekly or fortnightly) from:

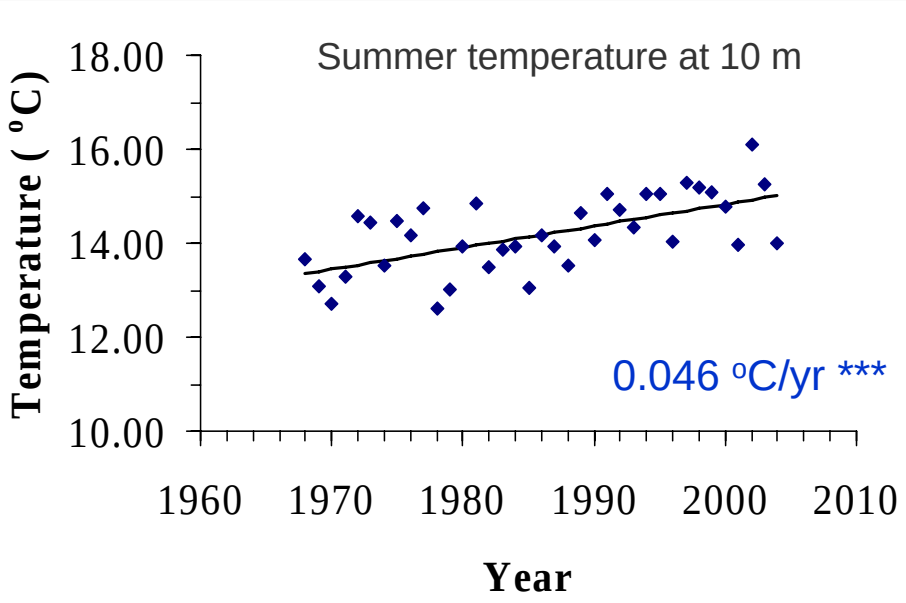
- From 1945- Windermere North Basin,
  Windermere South Basin
  Esthwaite Water
  Blelham Tarn
- From 1969- Grasmere
- From 1990- Derwent Water, Bassenthwaite Lake

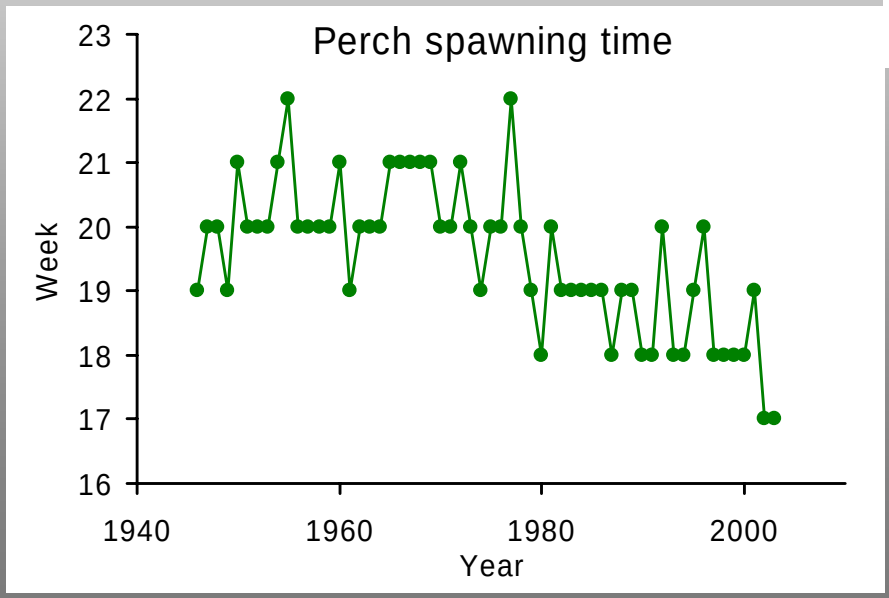
FRESHWATER BIOLOGICAL ASSOCIATION

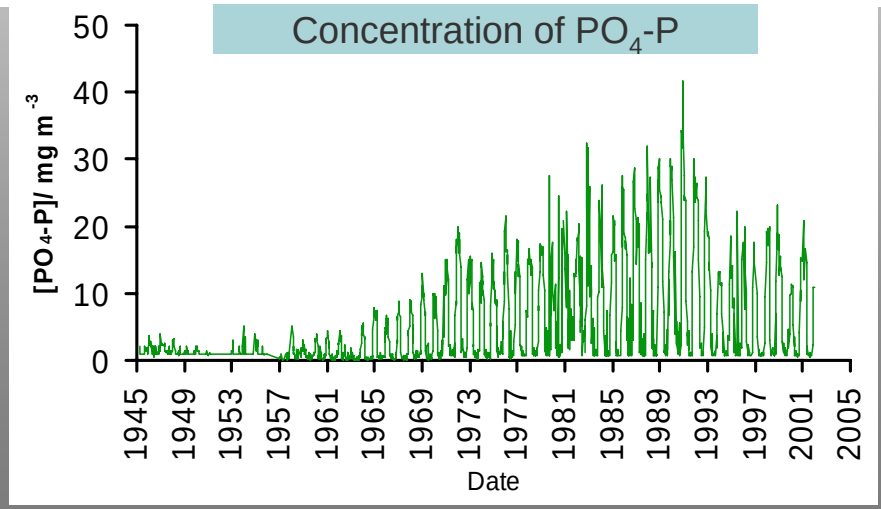
Examples of data

Measurements include:

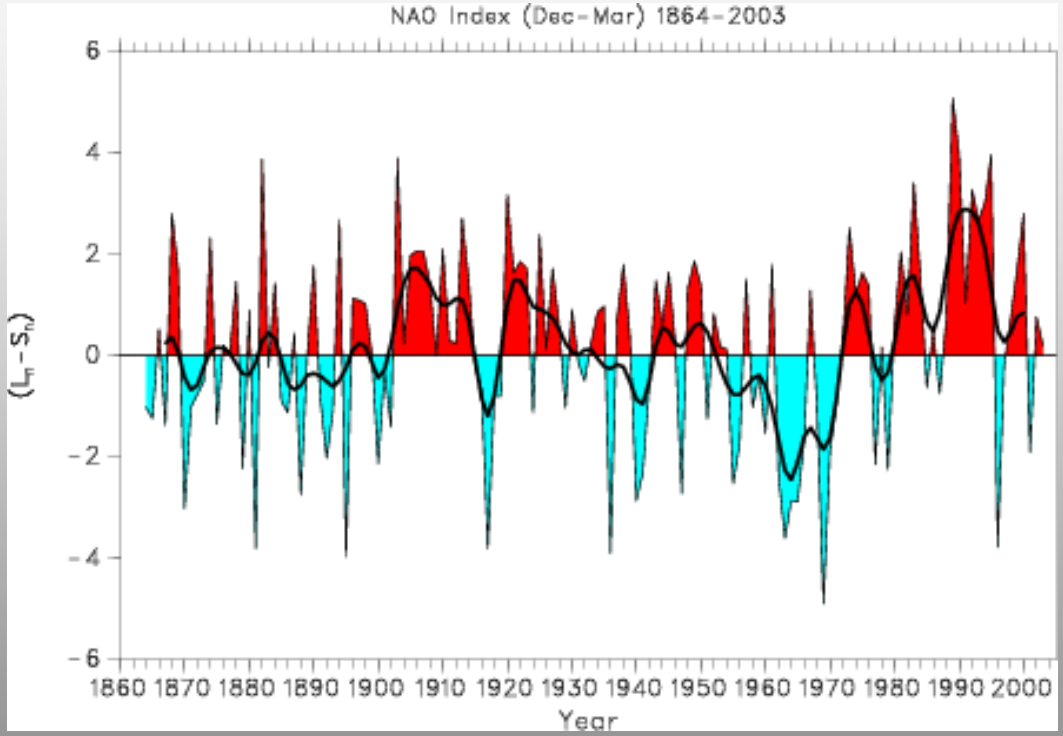
- Profiles of water temperature & O_2
- Light penetration
- Nutrient chemistry
- Phytoplankton species & abundance
- Zooplankton
- Fish populations



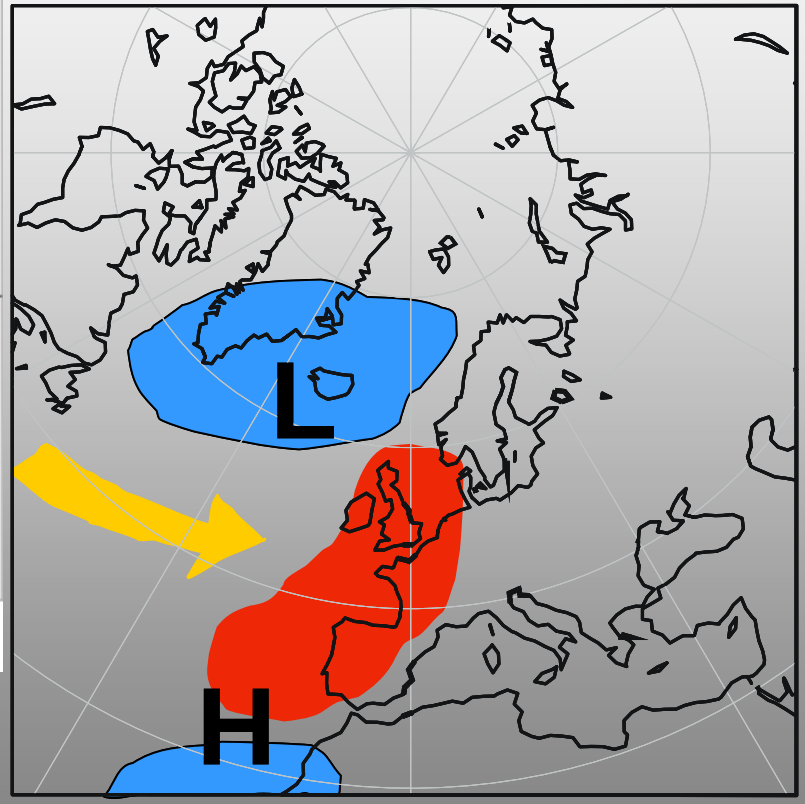




Regional patterns- the North Atlantic Oscillation & winter weather

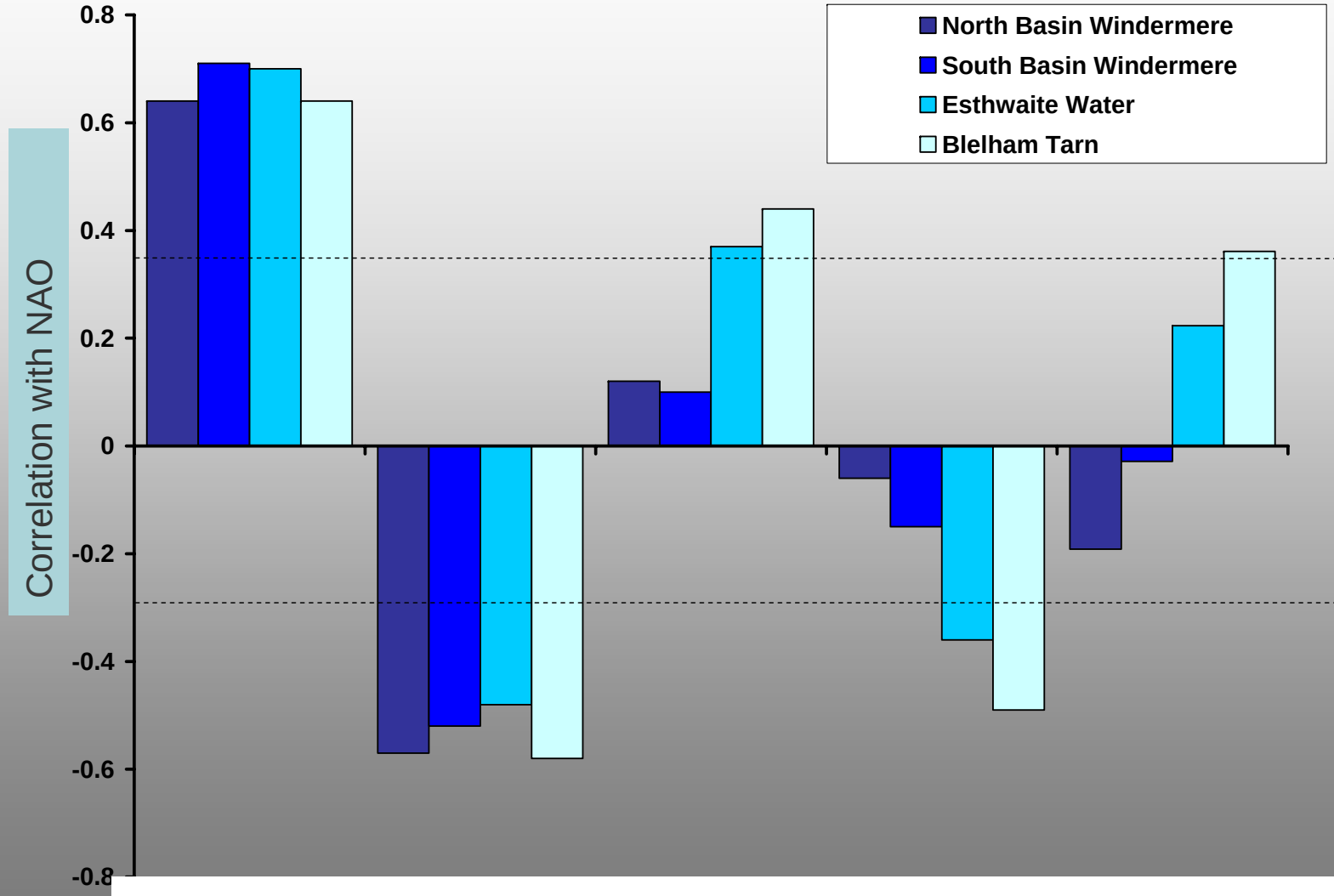


Positive NAO

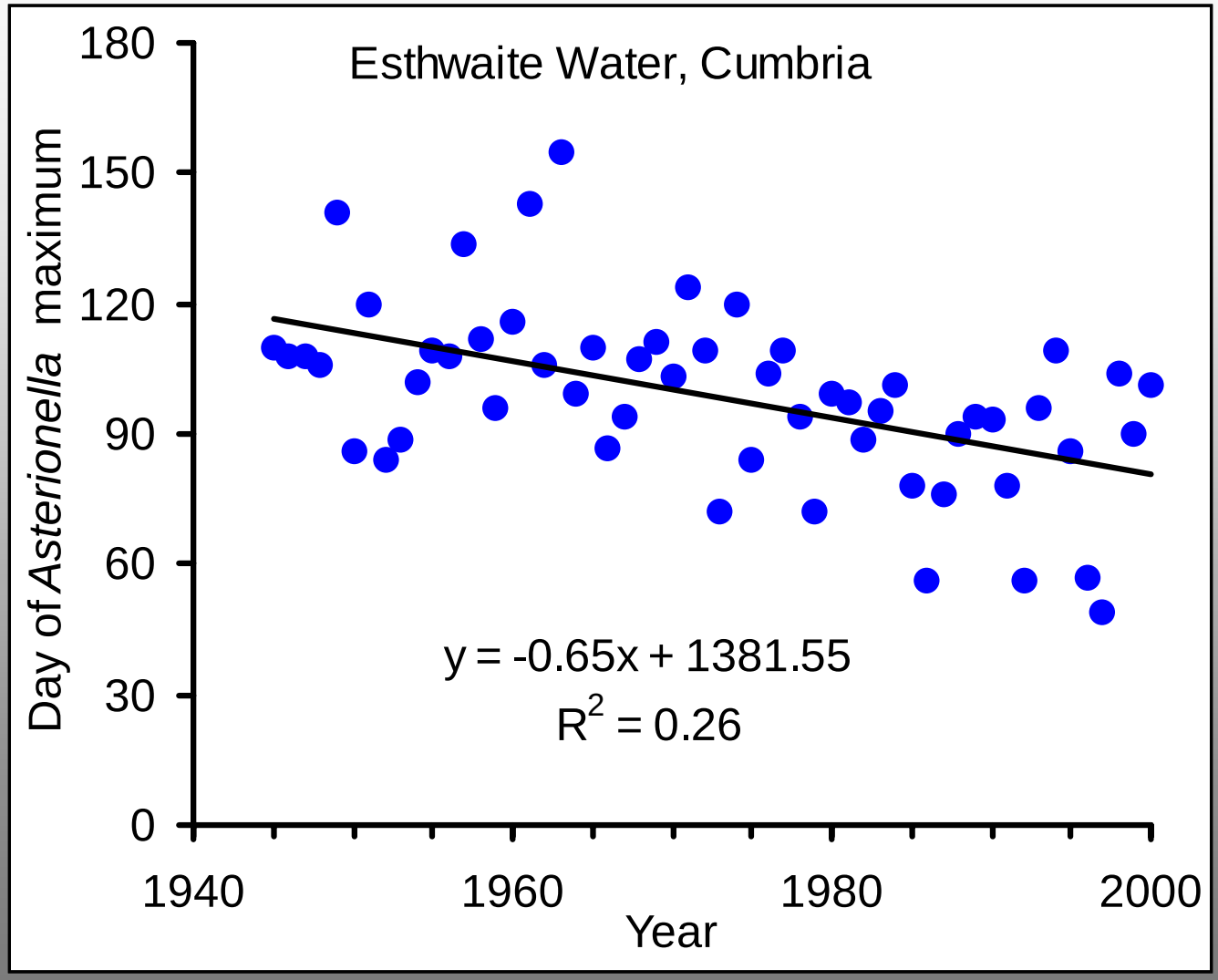


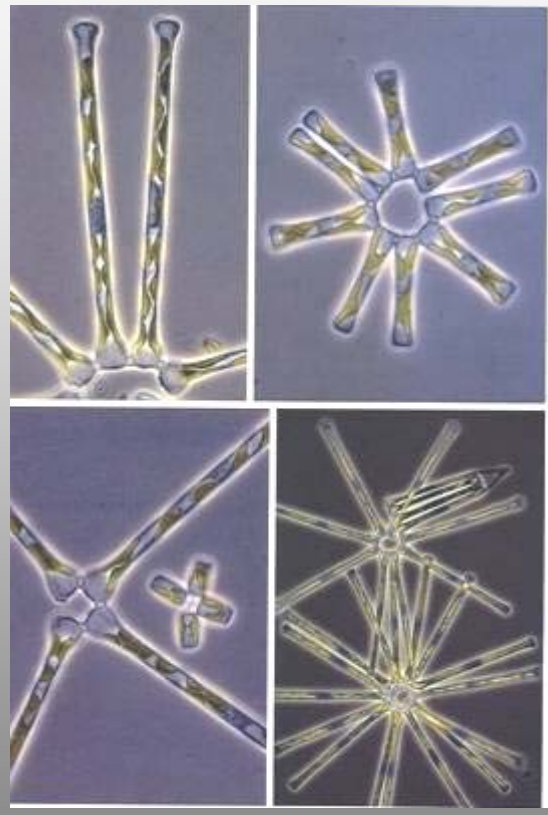
- **+ve NAOI produces relatively wet, mild, windy winters**
- **-ve NAOI produces relatively dry, cold, calm winters**

Differential sensitivity



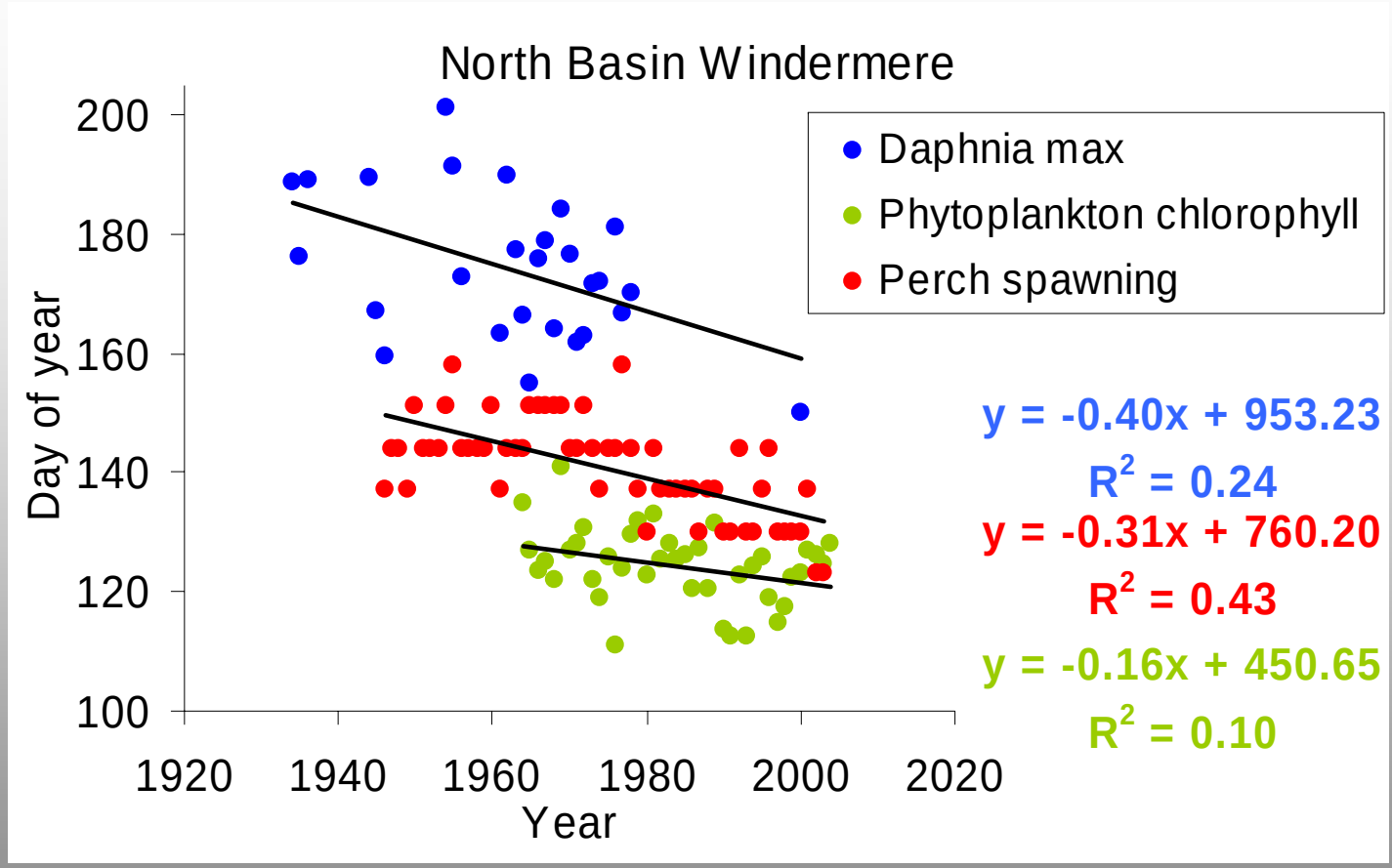
Changes in timing of events

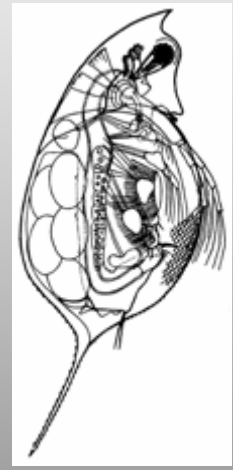




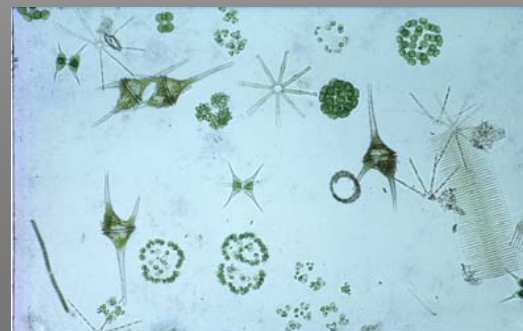
Asterionella formosa

Match-mismatch?





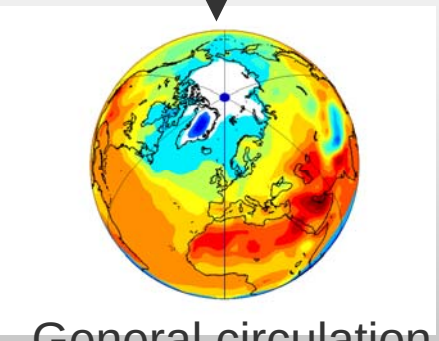
Cf. Walther *et al*. 2002	day yr^{-1}
Plant flowering/leaf break	0.14 – 0.31
Butterfly emergence	0.28 – 0.32
Bird migration	0.13 – 0.14
Bird breeding	0.19 – 0.48



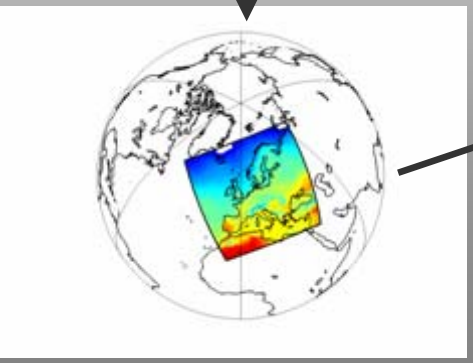
Current work & future prospects:

II –Forecasting lake responses to perturbation

Emission scenarios

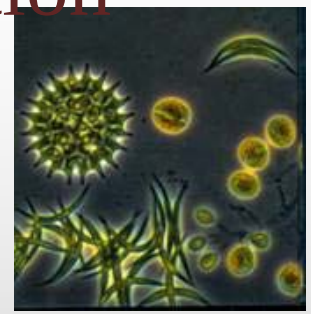


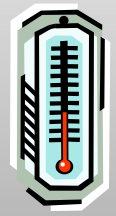
General circulation models (GCM)



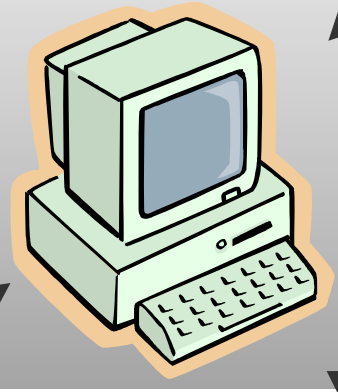
Regional circulation models (RCM)

Nutrient inflow

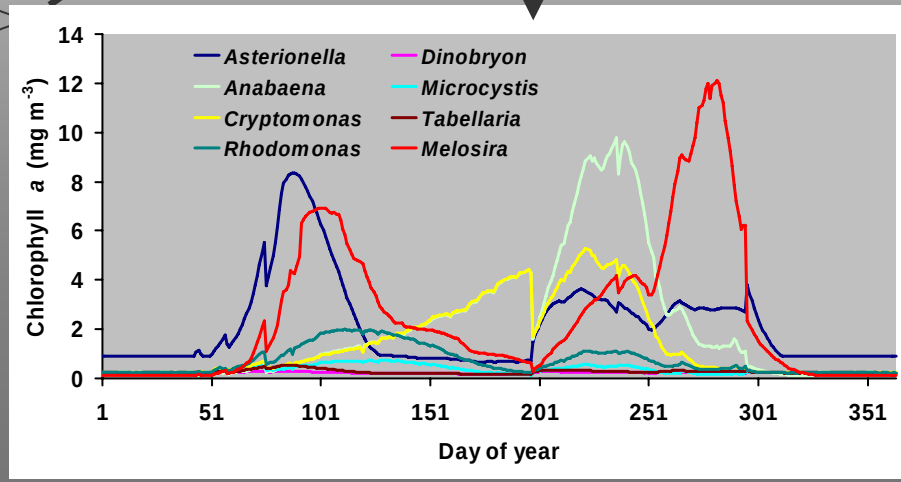




Weather scenarios



PROTECH



Conclusions

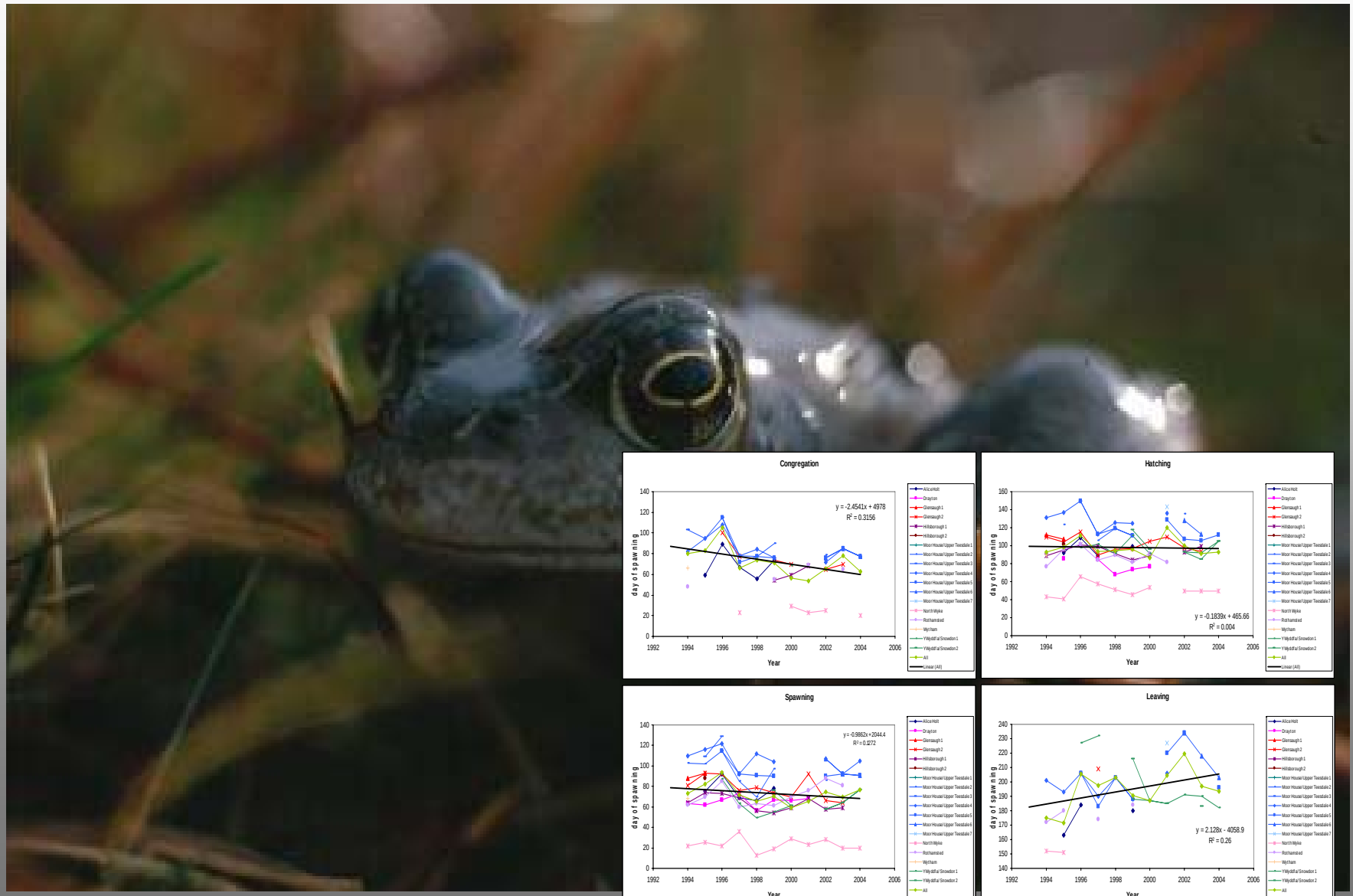
- Long-term data are invaluable in documenting how lakes have responded to perturbation in the past and forecasting how they may respond in the future
- Weather patterns (Gulf stream, NAO) will influence lakes regionally
- Not all lakes will be equally sensitive to given aspects of climate change
- Lakes are complex ecosystems that respond to changes in the catchment *and* atmosphere
- Modelling in conjunction with long-term data, is a powerful method of attribution and of forecasting responses to future conditions

Are we losing biodiversity? Why? And so what?

LTER sites measure biodiversity, pressures and ecosystem services.

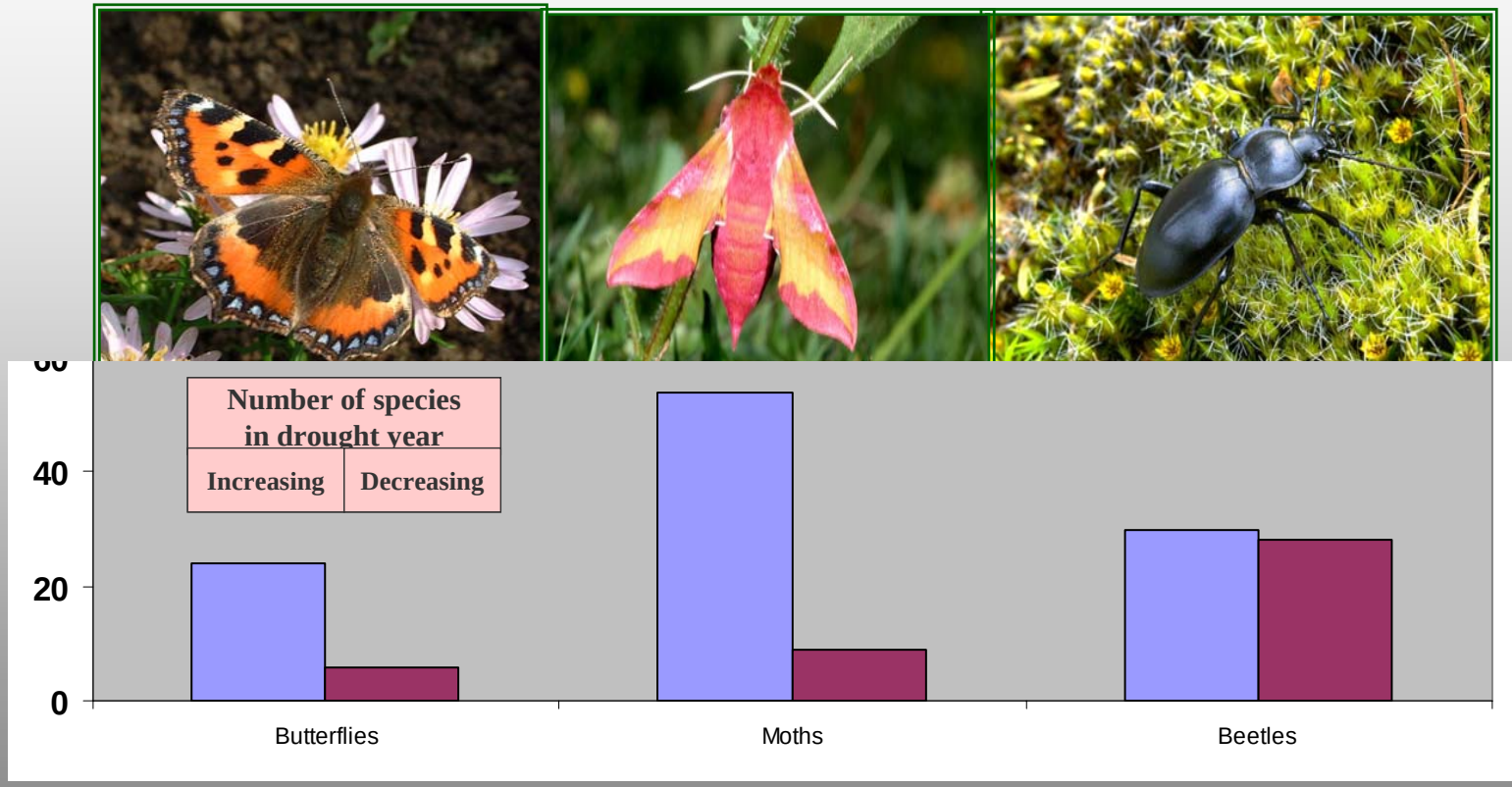
FROGS – CLIMATE EFFECTS ON LIFE HISTORY

Trends in breeding dates. Overall extension of breeding season



Towards indicators of Climate Change Impacts

Effects of 1995 drought on insects in the UK
(Data from 10 ECN sites)

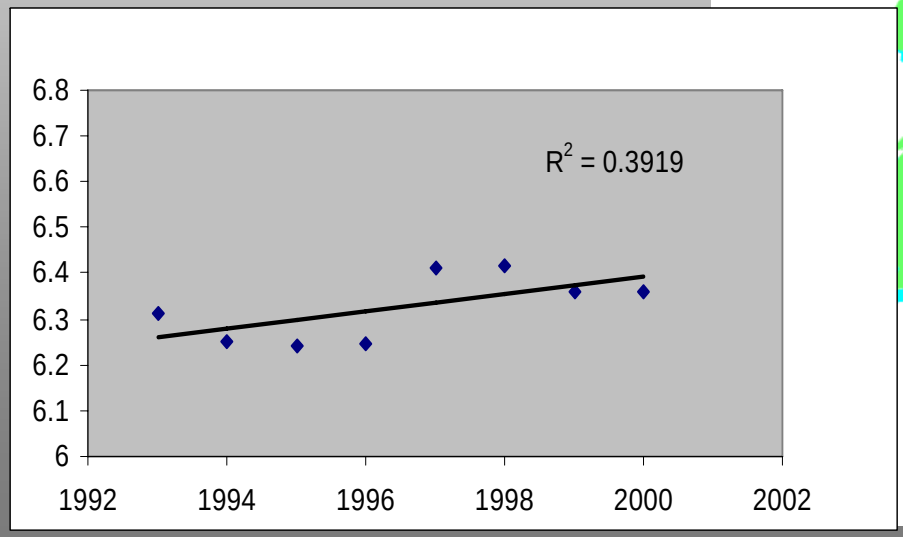


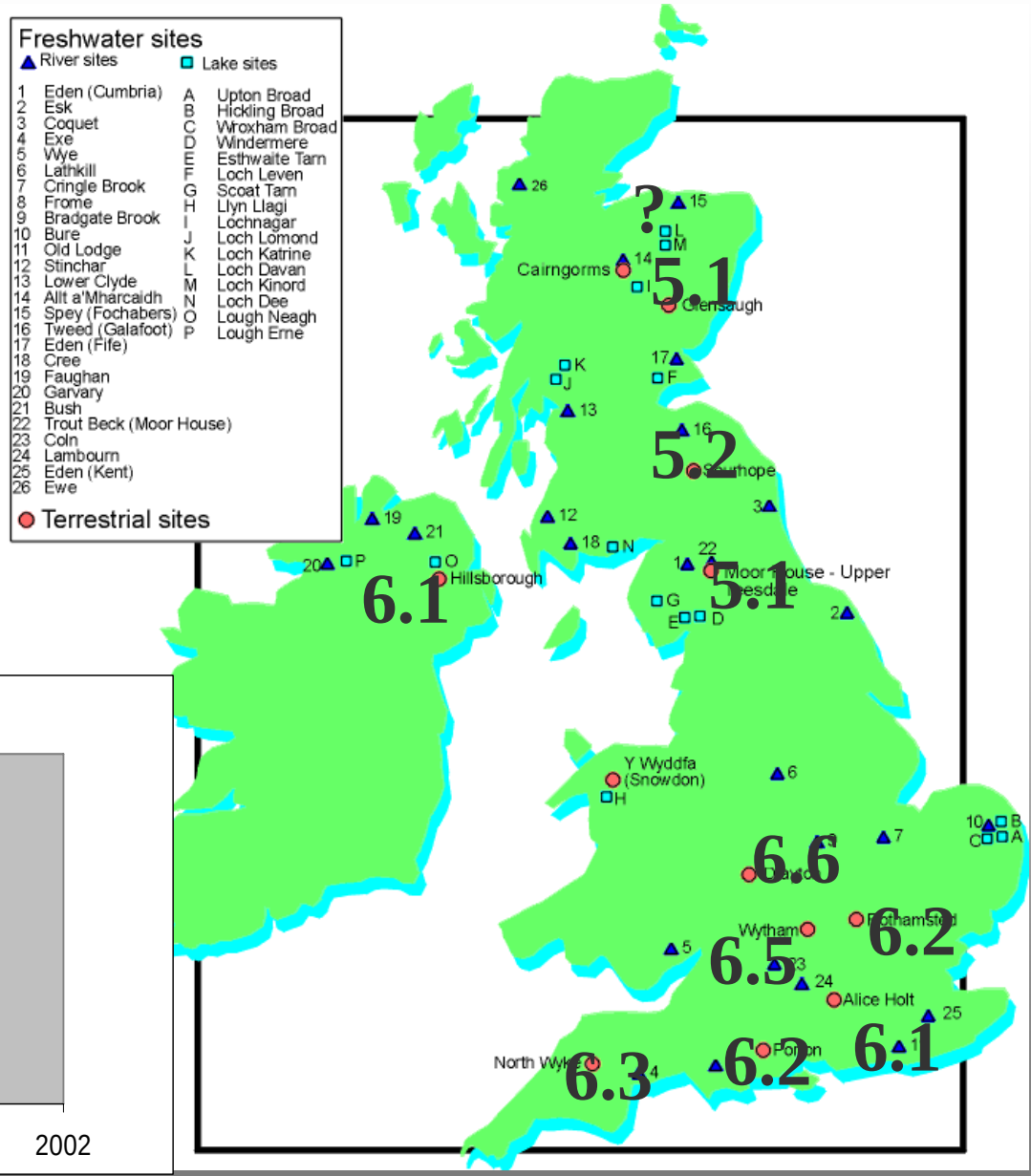
- can identify species of particular functional types that are likely to respond to climate change
- E.g southern species with high mobility

Morecroft et al (2003)

Changing Distributions – increases in “Southern” species

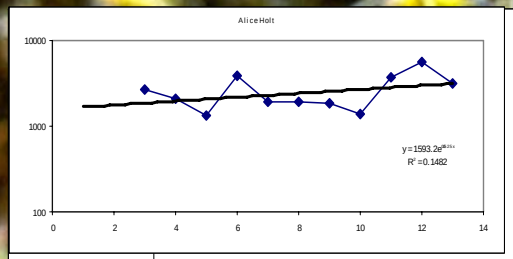
Ground Beetles
An Index of Southern-ness based on species’ distributions

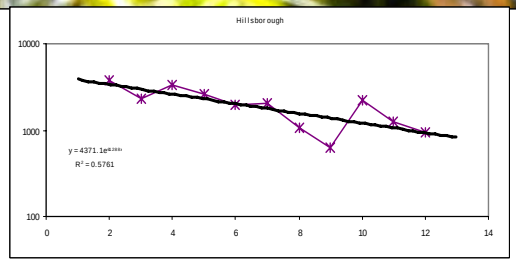


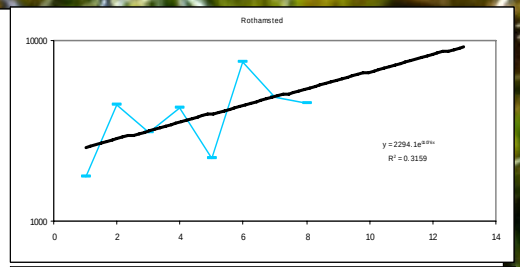


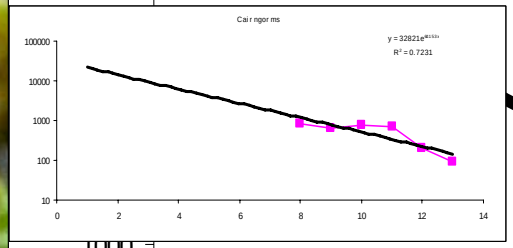
Roy Anderson DARD(NI)

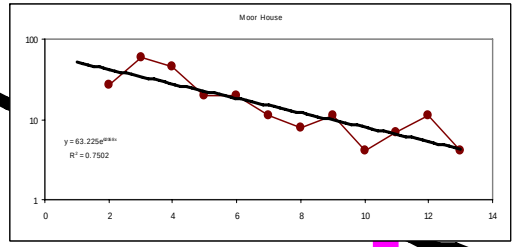
Carabid beetles– Key part of food chain,

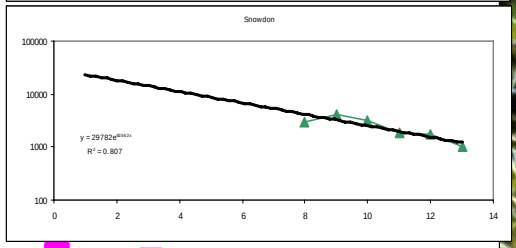


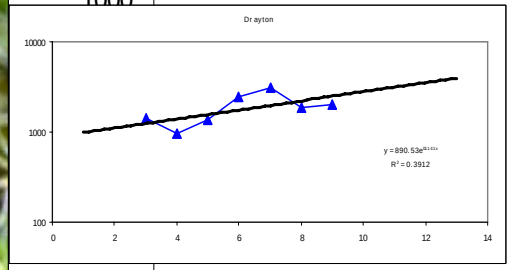


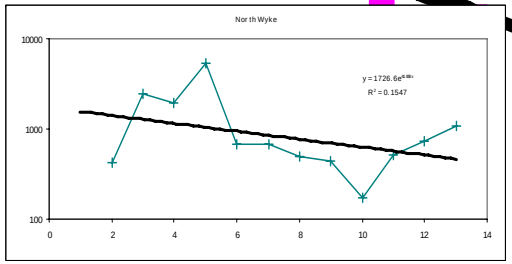


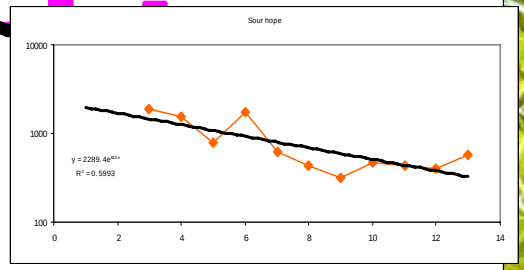


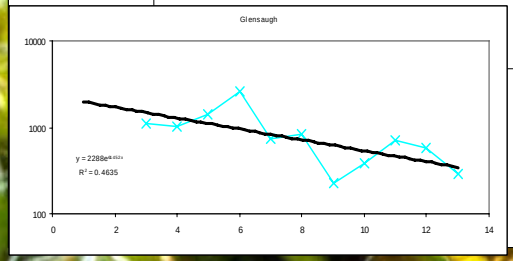


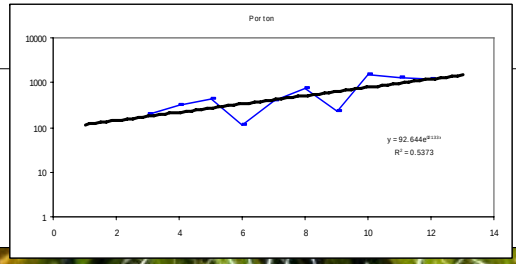


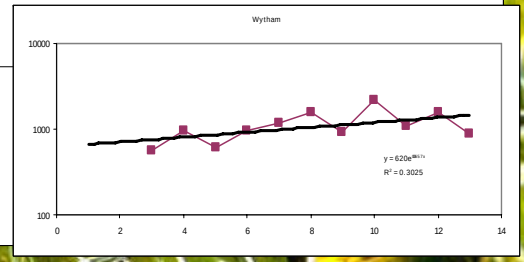




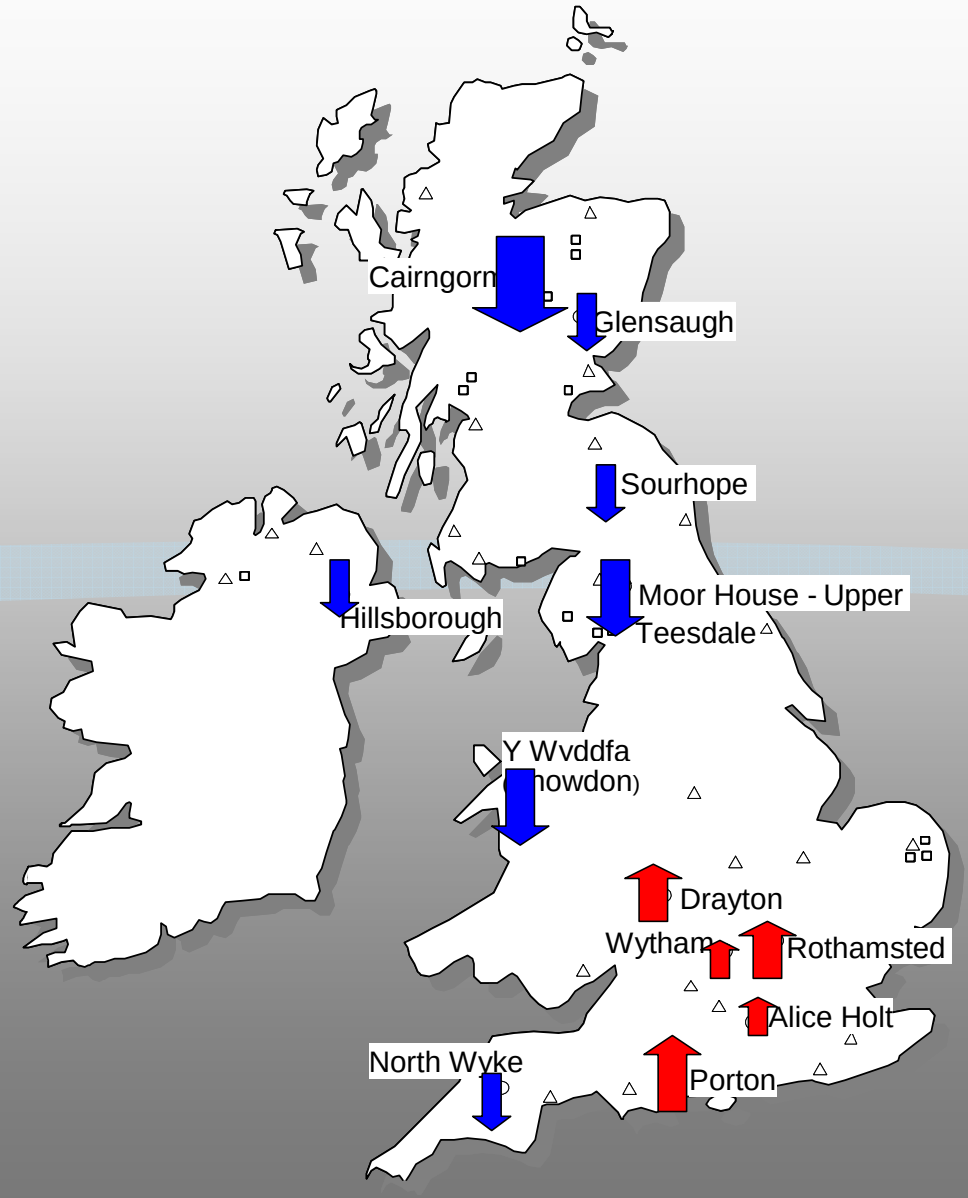






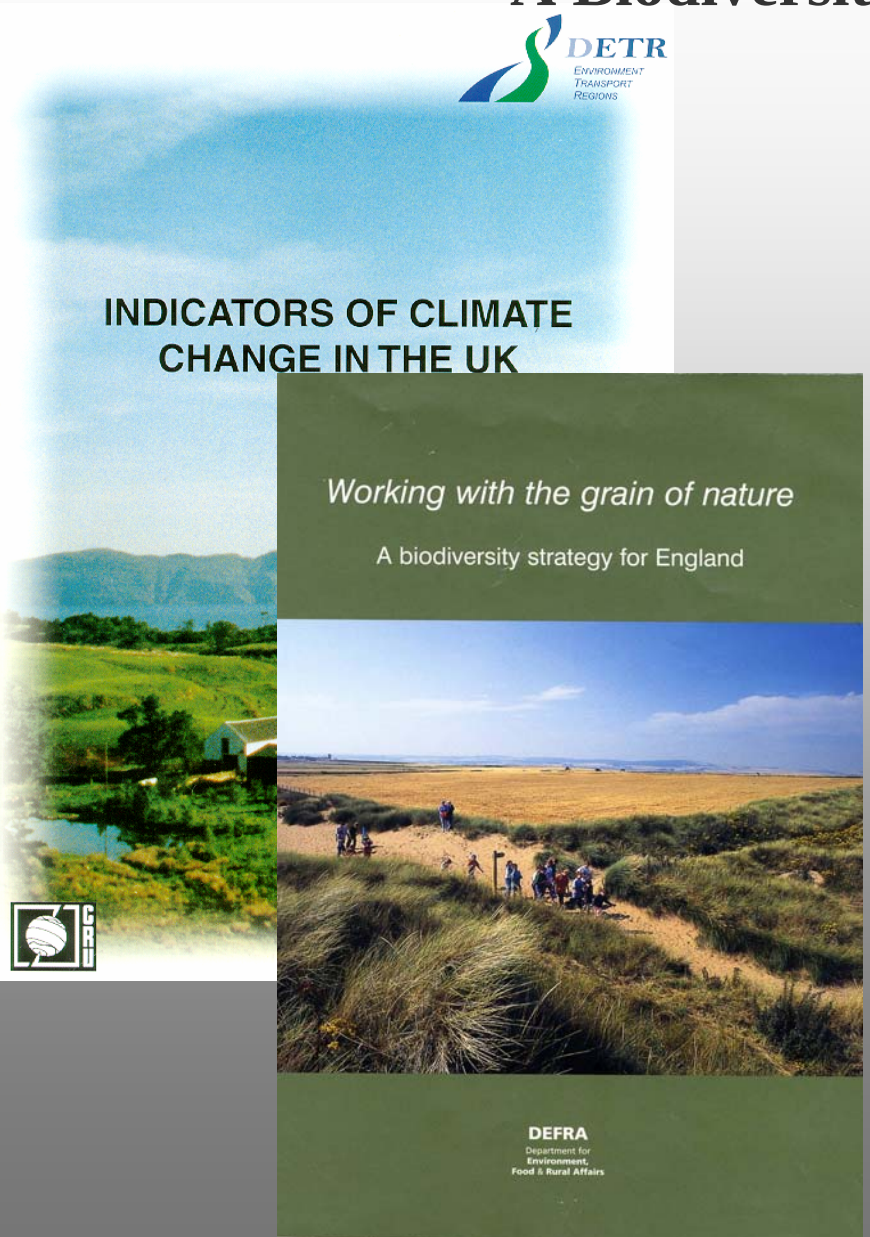


Carabids – Trends 1994-2003



Climate Impact Indicators

"A Biodiversity Strategy for England"



2002

"Indicator C1: a climate change impact indicator based on changes in the abundance of climate sensitive species in ECN sites"

COUNTDOWN 2010

Halt the loss of biodiversity

Biodiversity and climate change
UK & European Policy Context

MSOffic

DEFRA
Department for Environment, Food & Rural Affairs

ENGLISH NATURE

SCOTTISH NATURAL HERITAGE

1. Will climate change prevent us meeting our legal obligation to protect wildlife in designated sites?

2. How many sites and what measurements would we need to "prove" climate change and air pollution impacts on nature conservation sites?

MSOffice12 ate
, 2006-5-23

Targeted Monitoring Network – Design

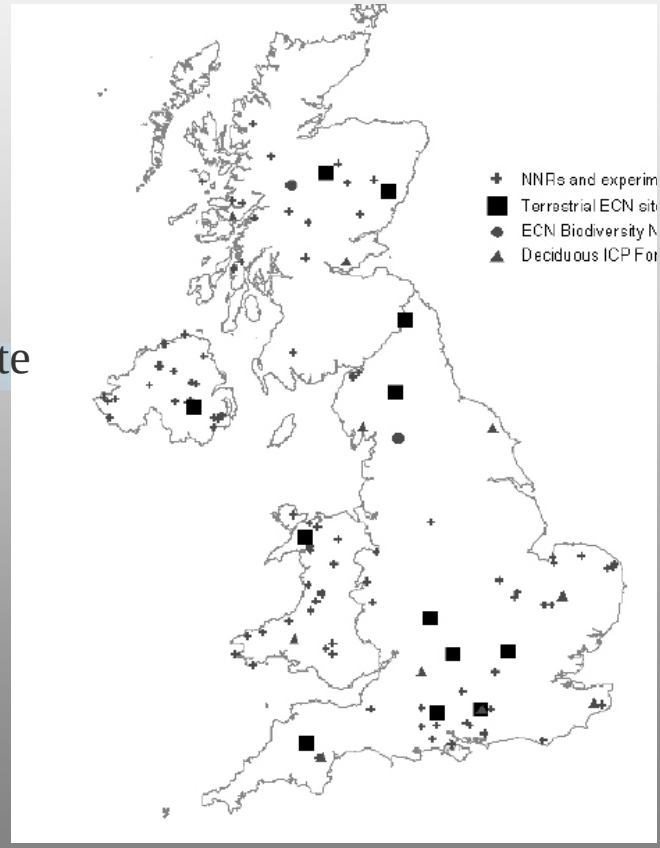
Compare sites in:

High v low climate change areas

High v low atmospheric pollution

Measurements

- Climate
- Air pollution
- Wet deposition - pH, nitrate, ammonium, sulphate
- Ammonia concentration - diffusion tubes
- Total nitrogen deposition
- Soil chemistry and physical description
- Vegetation composition
- Butterflies
- Birds
- Satellite remote sensing of phenology
- Site management

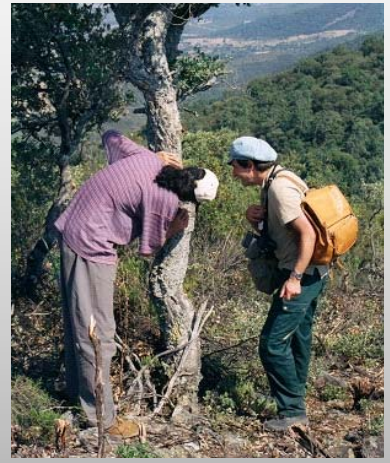


Cost – c. $10,000 /site/year

40-90 sites needed

LTER: Demonstration & Research Sites

Sites for science, training and education

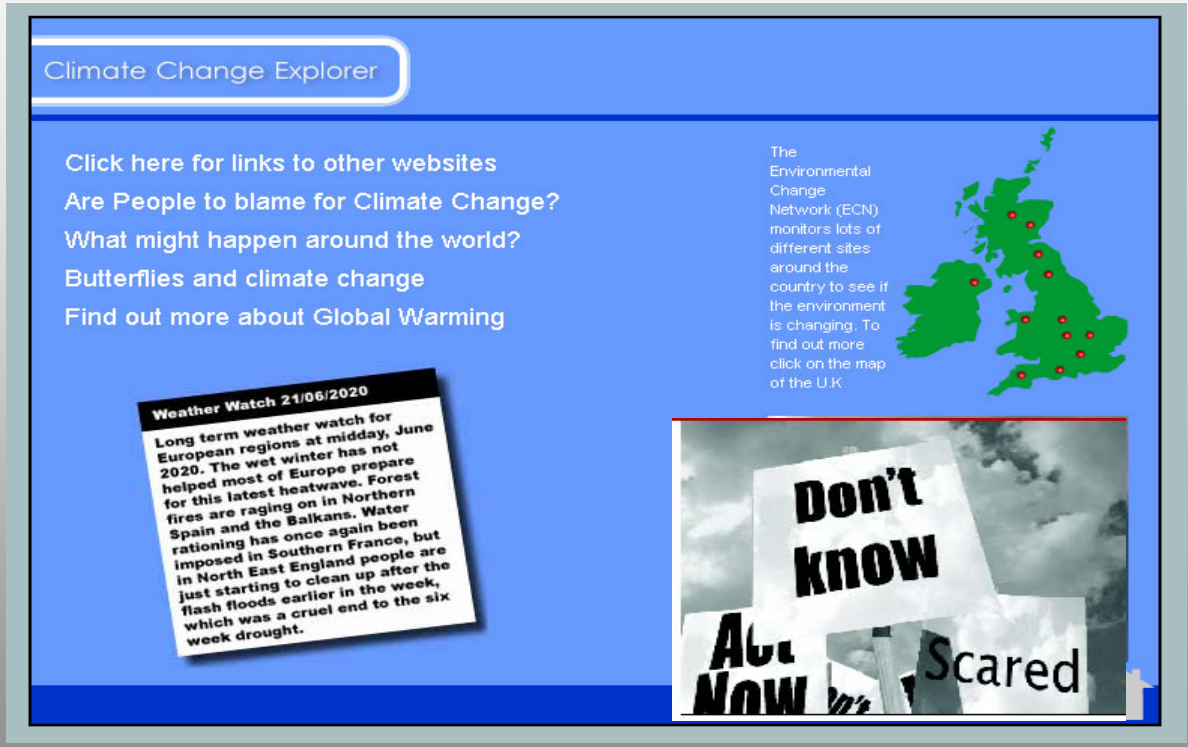


Understanding the processes of environmental change and their impacts on biodiversity and ecosystem services

Knowledge Management & Communication in ECN

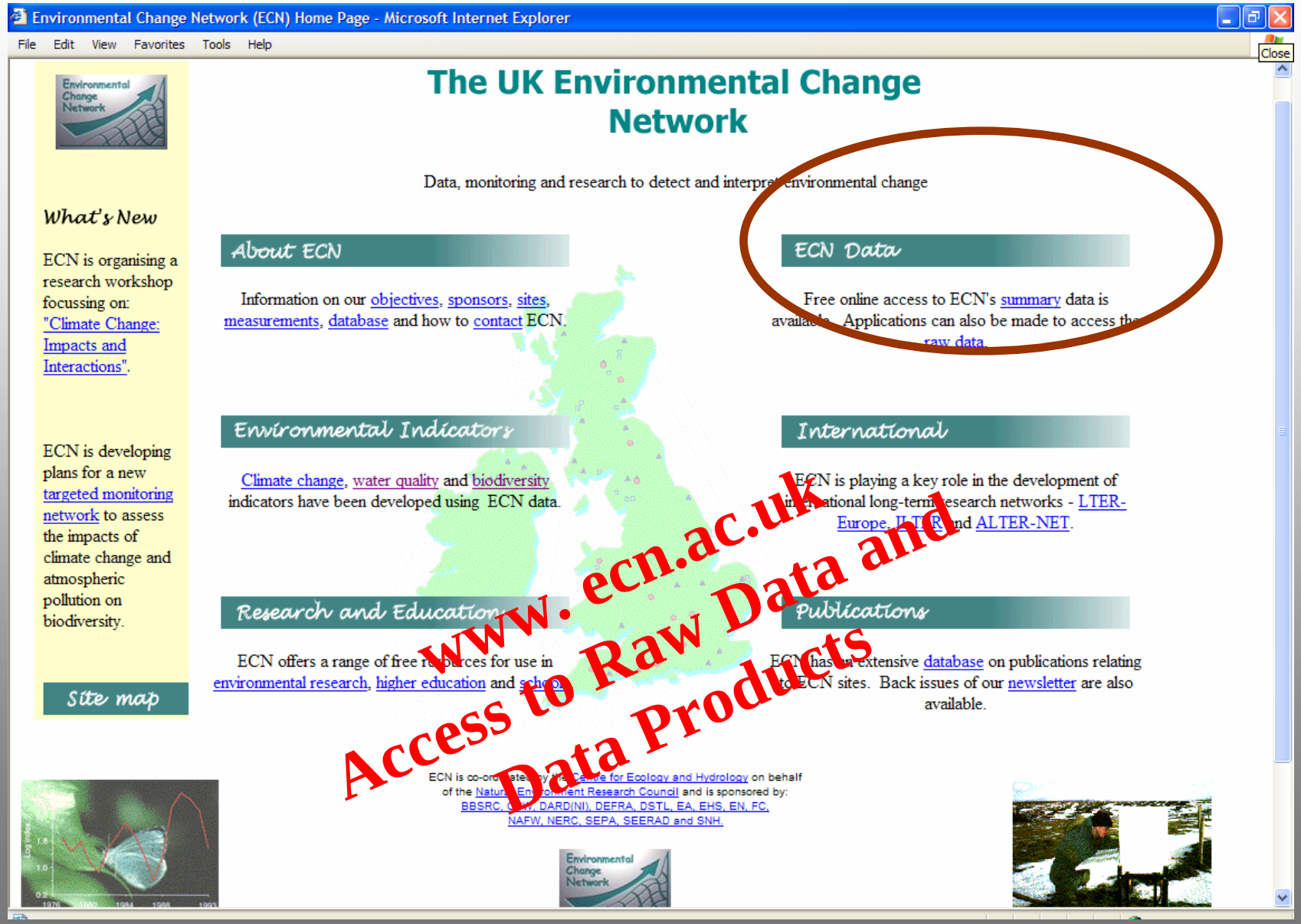
Educational Outreach
The “Climate Change Explorer”

working with artists and schools to inform people about climate change

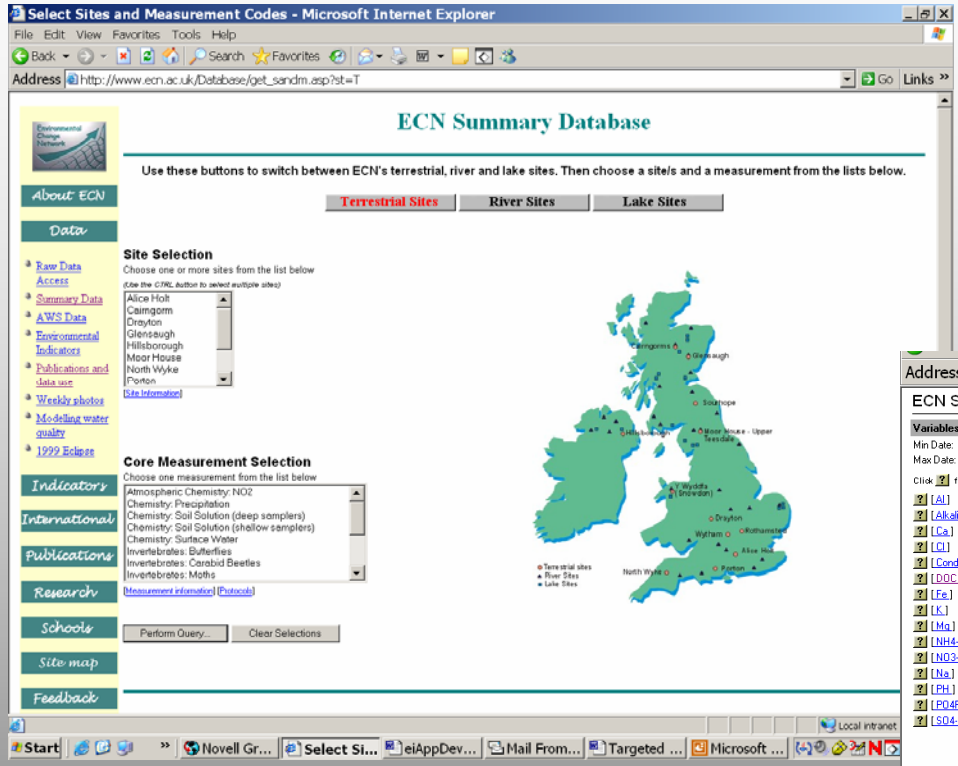


- Phase II – funded by Department of Environment to raise awareness of climate change amongst young people

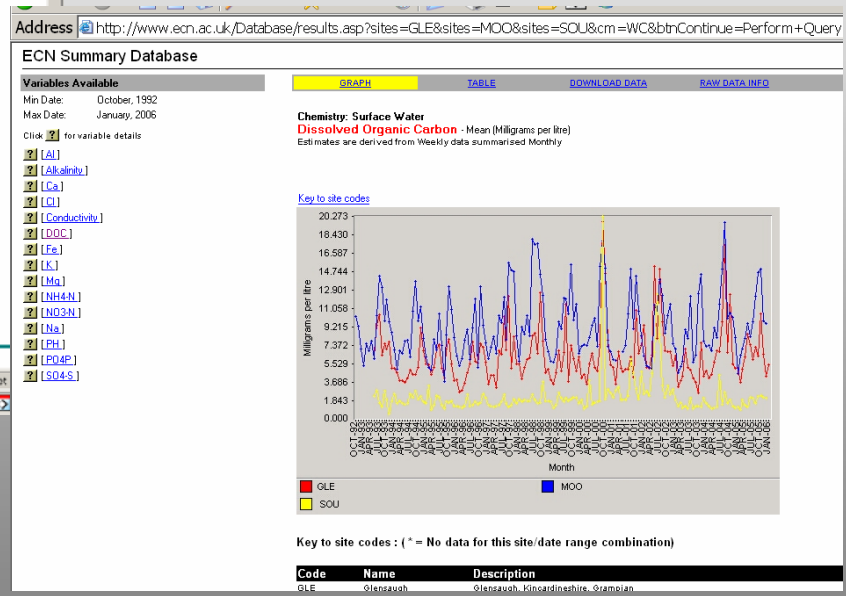
Open Access to Data



Summary Data - trends



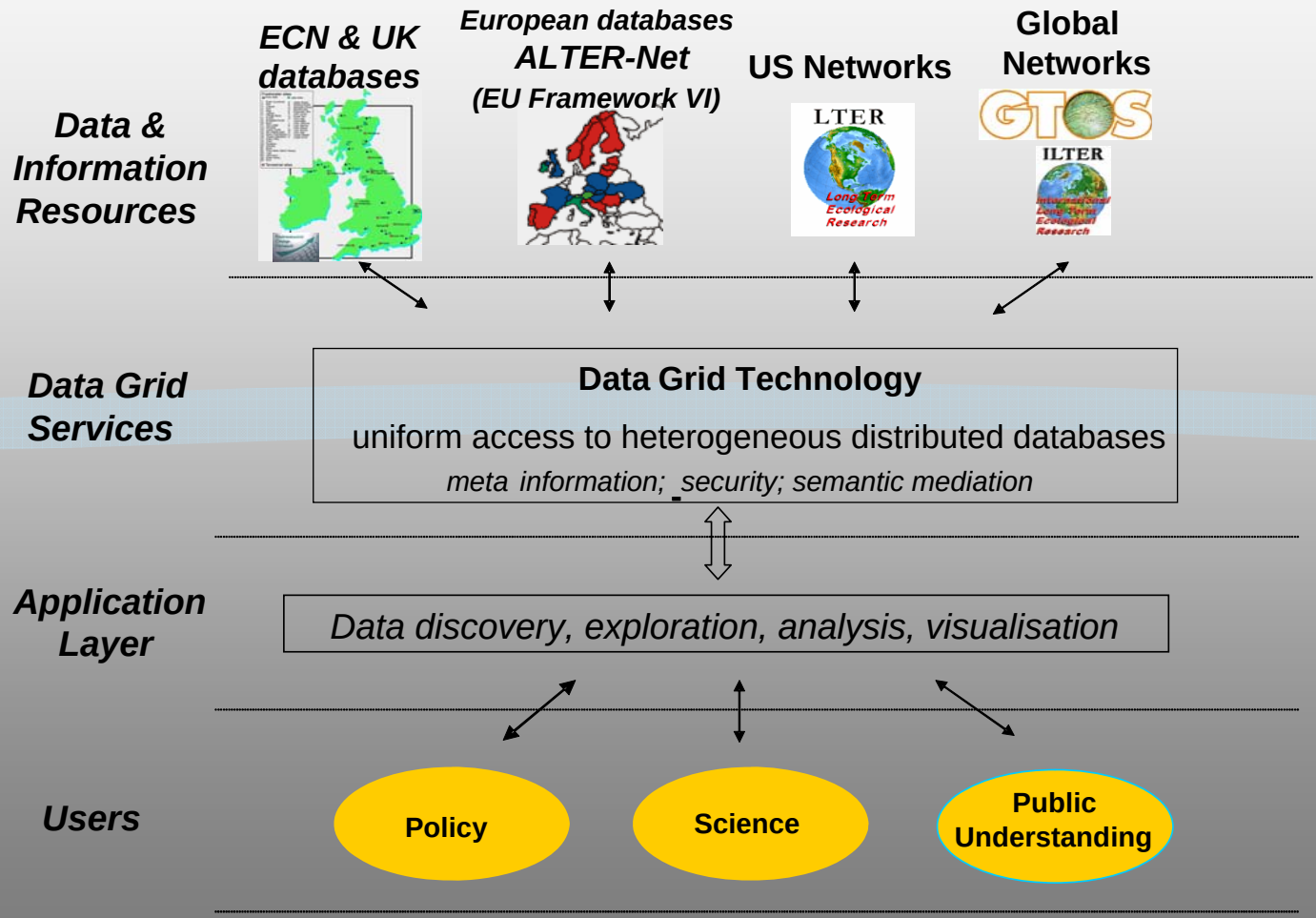
e.g. Water Quality
Dissolved organic carbon



Applications – Research
Surveillance

Joining up data for ecosystem and climate impact research

from data to knowledge for environmental management and policy.



Detecting and attributing change

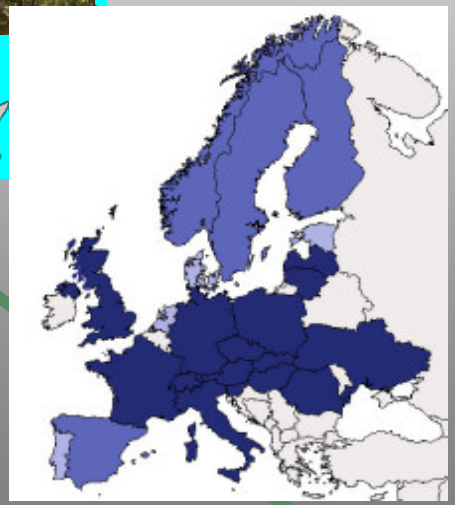
International Networks

European Networking for Biodiversity and Ecosystem Research: capacity building

local

LTER Sites → - how and why is biodiversity changing?
- forests, inland waters
- site management recommendations

National Networks → • inform national action plans

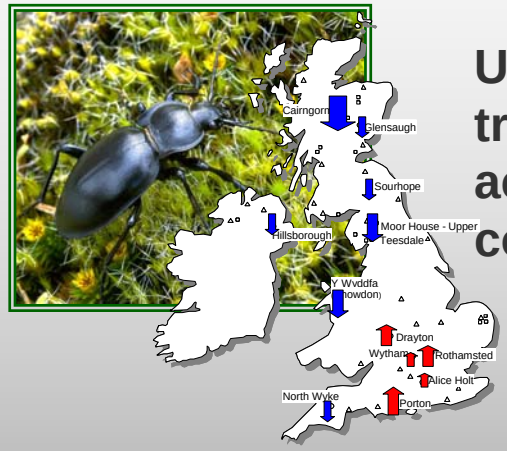


European Networks
www.lter-europe.ceh.ac.uk →
- Assessment of policies
  - in protected areas
  - wider countryside,
  - cross-sectoral issues

LTER-Europe – established June 2007
Chair Michael Mirtl: UBA, Austria

Knowledge from European LTER sites

Examples:

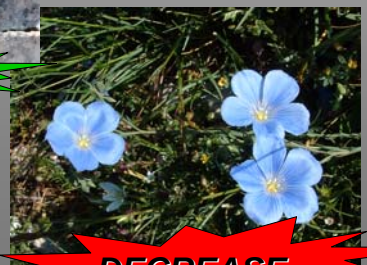


UK:
trends vary across the country

Responses:
management and policy response options e.g. habitats directive, water framework directive

Long-term ecosystem research across Europe

Italy:
climate change impacts on mountain plants



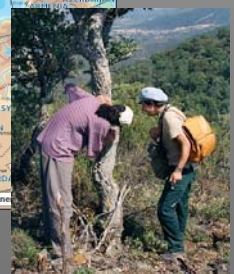
Romania:
Valuation of ecosystem services in protected wetlands

Adding the human dimension

Decisions affecting biodiversity must take into account the social, cultural and political context

Cairngorms, UK

Lower Danube, Romania

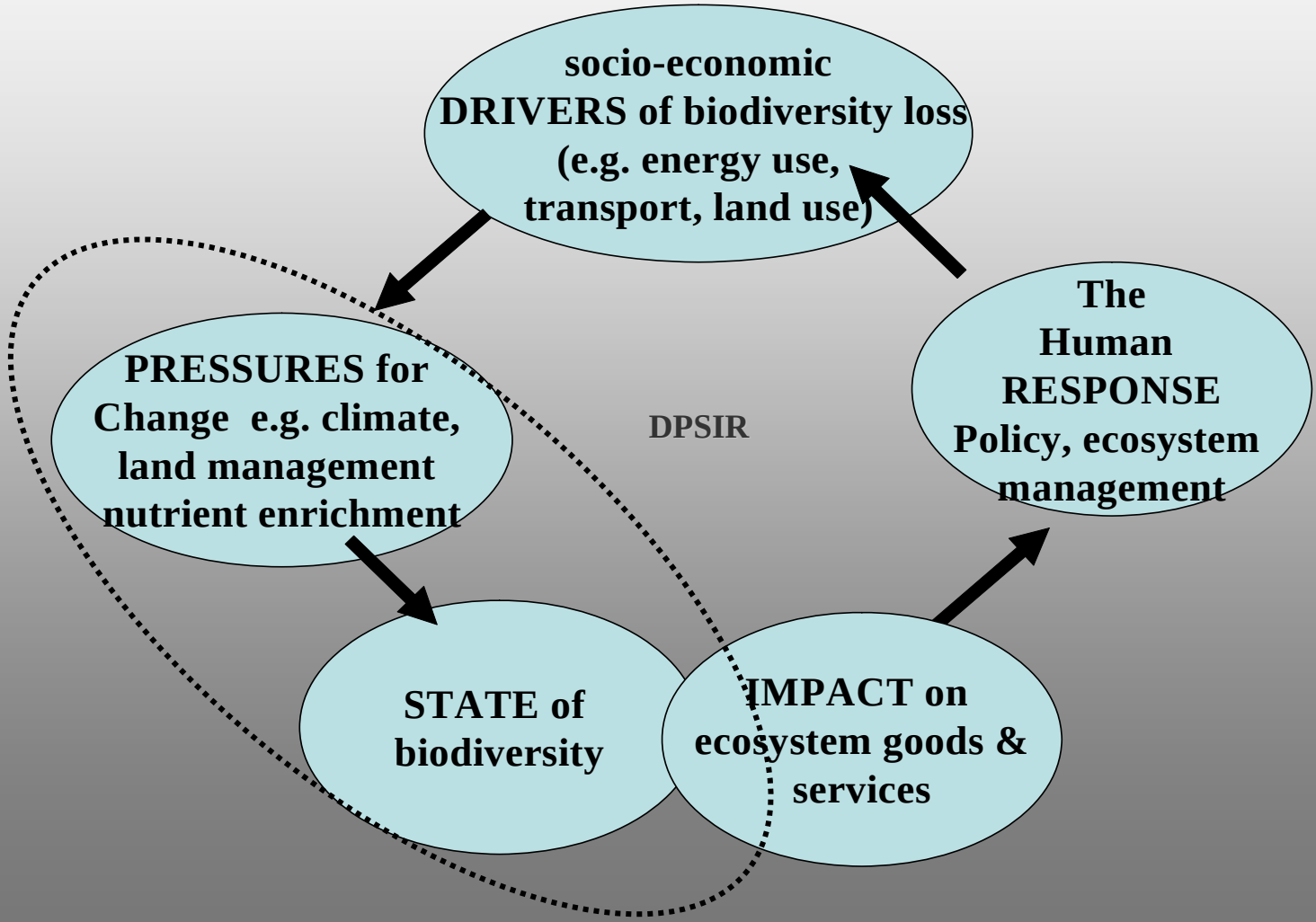


A network of sites in which social scientists and ecologists work together:

- Deliberative events
- Public attitudes
- Conflict resolution
- Policy

The DPSIR Indicator and Research Framework

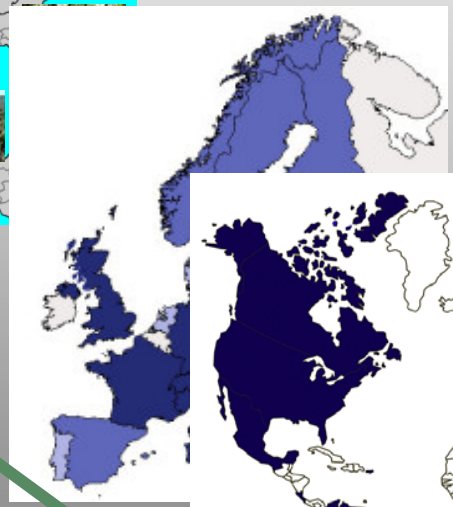
Drivers:Pressure:State:Impact:Response (DPSIR)



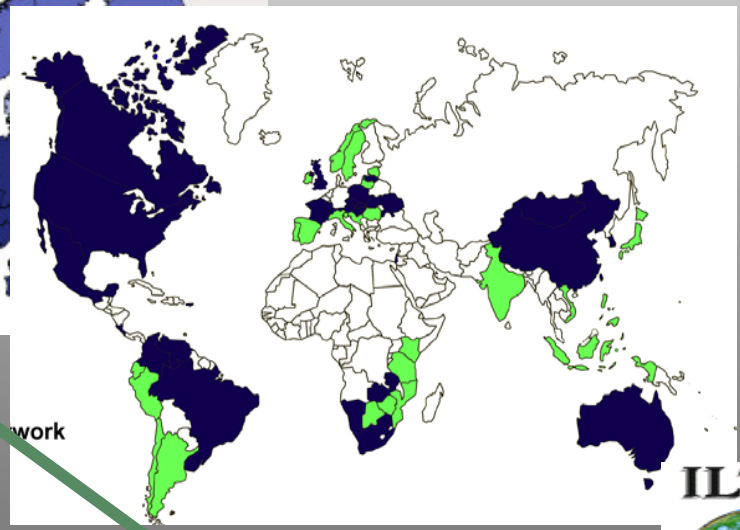
Global Networking of Ecosystem research sites

LTER Sites

National Networks



Regional Networks



local

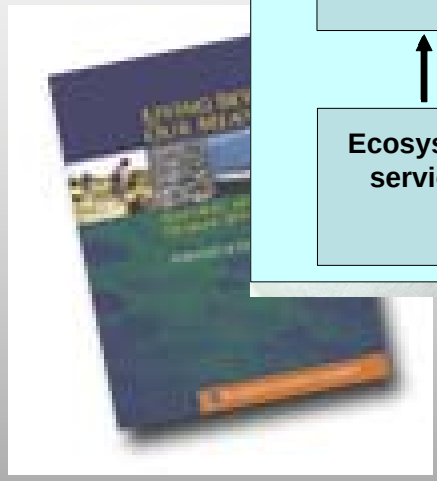
global

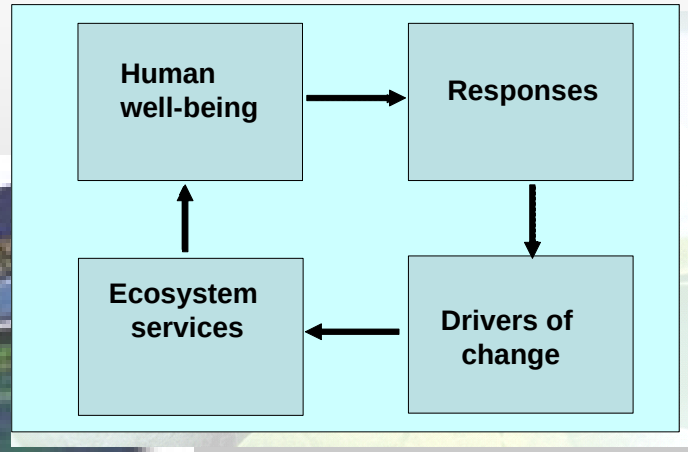
Global ILTER

www.ilternet.edu

Some Global Drivers

- **Millennium Ecosystem Assessment:**
  - need for scientific information on the consequences of ecosystem change for human well-being and options for responding.





- **Global Earth Observation System of Systems**
  - Integrated Earth Observation Systems linking in situ and remote sensing data
    - Gleneagles G8 Summit – 2005
    - Commitment to implement in member states and developing countries
    - Address 9 societal benefit areas including climate change and biodiversity

ILTER and Ecosystem and Biodiversity Research: Long-term ambitions

To provide a global infrastructure for process based research, observations, and training relevant to global change and sustainable development issues.

A key component of national, regional and global programmes (GEOSS)

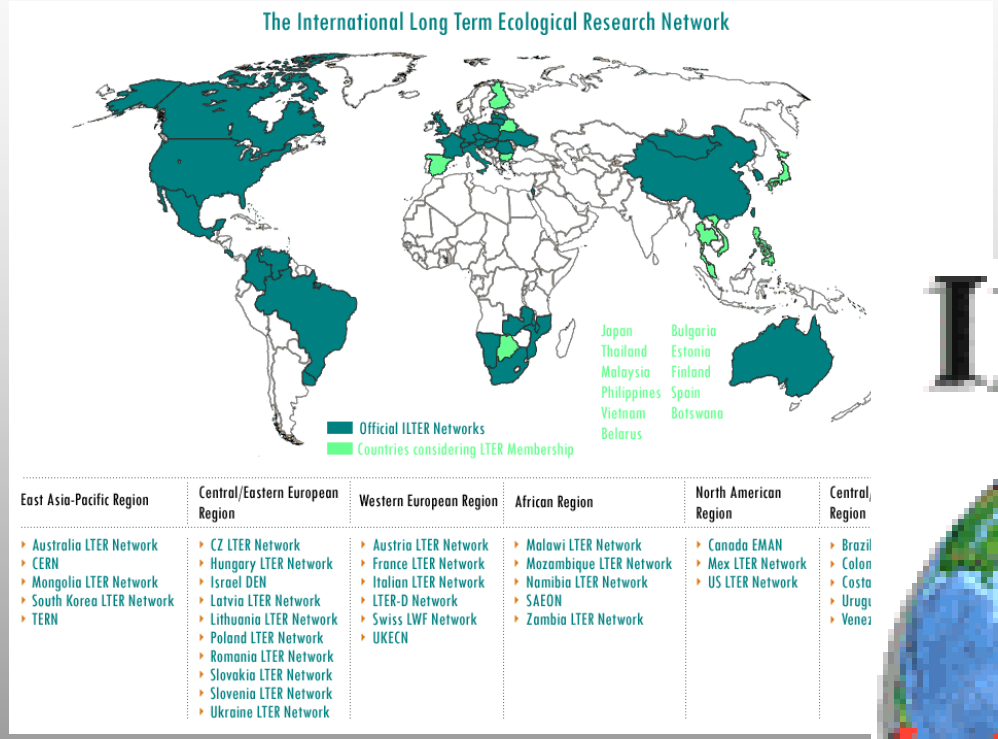
Relevant global scale research outcomes and products

Some priority research questions based on national responses

Synthesis from ILTER, Mexico Nov 2005

1. What are the effects of key pressures and their interactions on biodiversity?
   - Climate change, air pollution (N,S), land use change (including GM crops), grazing ……
2. Relationship between biodiversity and ecosystem services
3. Biodiversity assessment and indicators
   - Surrogates for biodiversity assessment
   - Use of functional groups
   - Measures of critical natural capital
4. Critical thresholds
   - The point at which loss of biodiversity affects ecosystem services
   - Have we already gone beyond that point?

ILTER – The Future For Global Ecosystem Research



East Asia-Pacific Region	Central/Eastern European Region	Western European Region	African Region	North American Region	Central/ Region
Australia LTER Network	CZ LTER Network	Austria LTER Network	Malawi LTER Network	Canada EMAN	Brazil
CERN	Hungary LTER Network	France LTER Network	Mozambique LTER Network	Mex LTER Network	Colon
Mongolia LTER Network	Israel DEN	Italian LTER Network	Namibia LTER Network	US LTER Network	Costa
South Korea LTER Network	Latvia LTER Network	LTER-D Network	SAEON		Urugu
TERN	Lithuania LTER Network	Swiss LWF Network	Zambia LTER Network		Venez
	Poland LTER Network	UKECN			
	Romania LTER Network				
	Slovakia LTER Network				
	Slovenia LTER Network				
	Ukraine LTER Network