Understanding the impacts of climate change on wildlife

Tom Oliver

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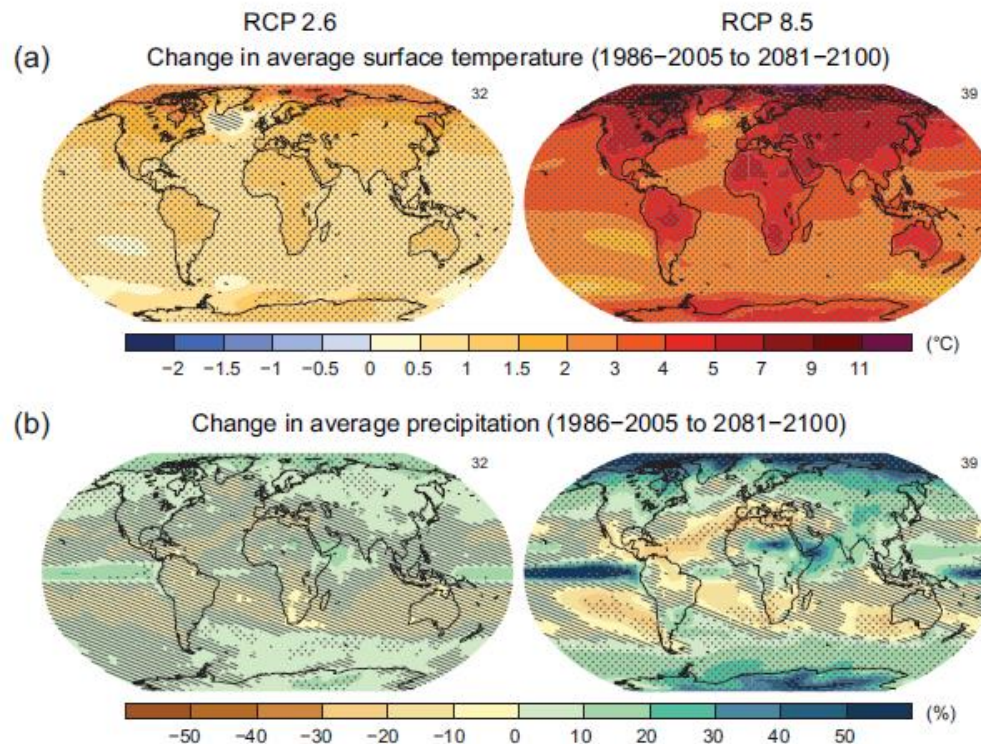🐦 **@Dr_Dolittle_81**

University of Reading

Climate change

Warming of the climate system is *unequivocal*, and since the 1950s, many of the observed changes are *unprecedented* over decades to millennia (IPCC, 2013)

RCP 2.6   RCP 8.5

(a) Change in average surface temperature (1986−2005 to 2081−2100)

(°C)
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11

(b) Change in average precipitation (1986−2005 to 2081−2100)

(%)
-50 -40 -30 -20 -10 0 10 20 30 40 50

IPCC projected long-term changes in climatic means

IPCC, 2013: Summary for Policymakers

Biological records

Biological records

Adonis blue
Polyommatus belargus

Small copper *Lycaena phlaeas*
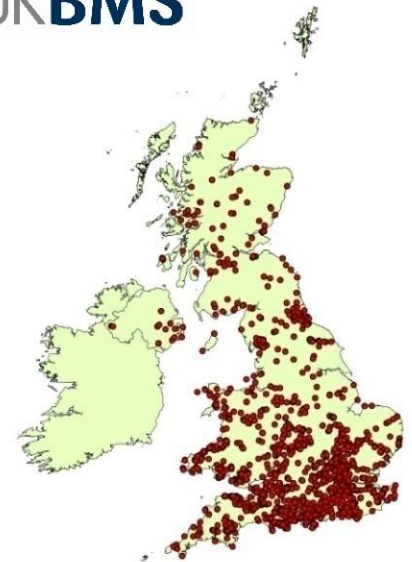
Comma
Polygonia c-album

Green hairstreak
Callophrys rubi
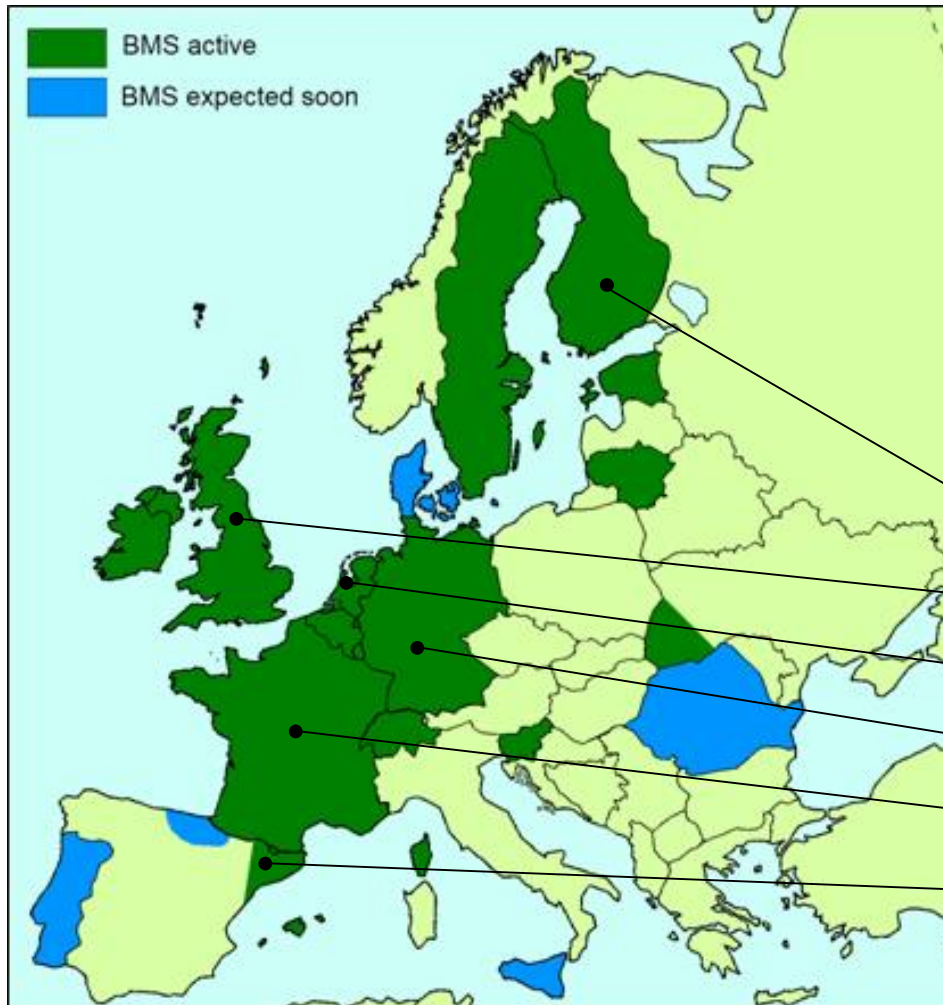
Long-term population monitoring

Butterfly Monitoring Schemes
- First UK scheme set up 1976
- C. 2500 transects (1200 active)
- 768,780km of butterfly transects walked-equivalent to a trip to the Moon!

UK**BMS**

Image credit: van Swaay

Long term population monitoring

Expansion of standardised 'Pollard walk' methodology across Europe

Longest-running schemes

| Country	Year	Sites
Finland	1999	70
UK	1976	1200
Netherlands	1990	950
Germany	2005	400
France	2002	100
Catalonia	1994	115

Adapted from van Swaay

Observed climate impacts: 1- **Phenology**

- Changes in the timing of biological events
- Butterfly emergence and peak flight dates have advanced over time
- Also there are spatial patterns…
- Concerns are for temporal mismatch with dependent species

SPATIAL PATTERN
Common blue

TEMPORAL PATTERN
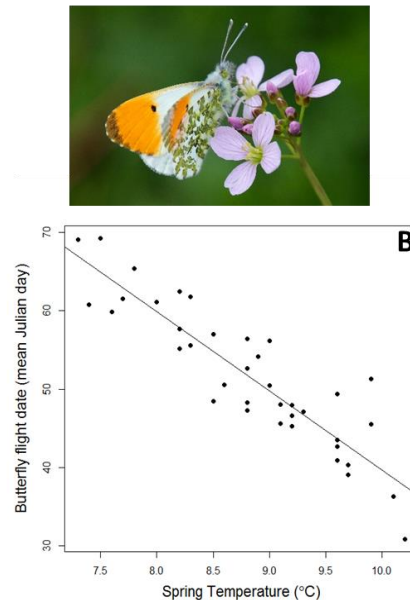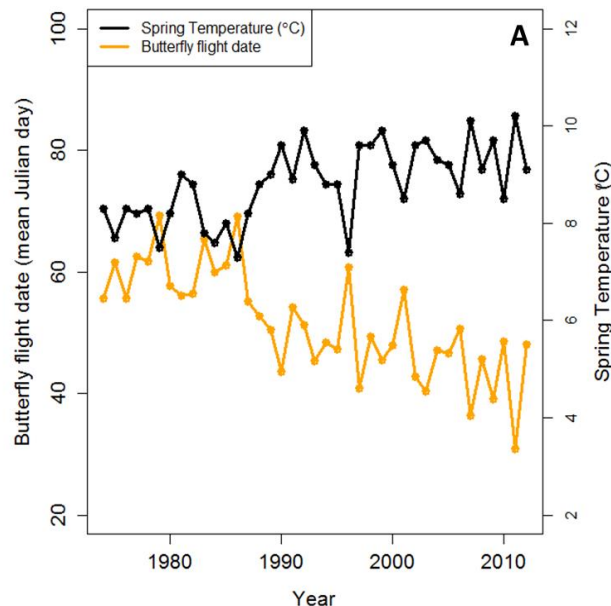
Hodgson et al. (2011) *Glob. Ch. Biol.*
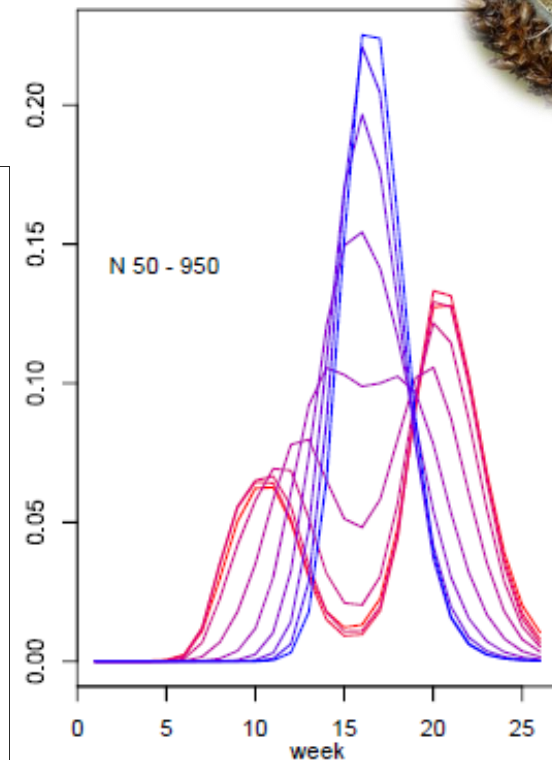
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SPATIAL PATTERN
Common blue

TEMPORAL PATTERN

Species	Change in date of mean abundance (days)
Green Hairstreak	-12***
Brown Hairstreak	-3
Purple Hairstreak	-10*
White-letter Hairstreak	-16***
Black Hairstreak	-23***
Silver-studded Blue	-15**
Northern Brown Argus	-11*
Chalk-hill Blue	-8*

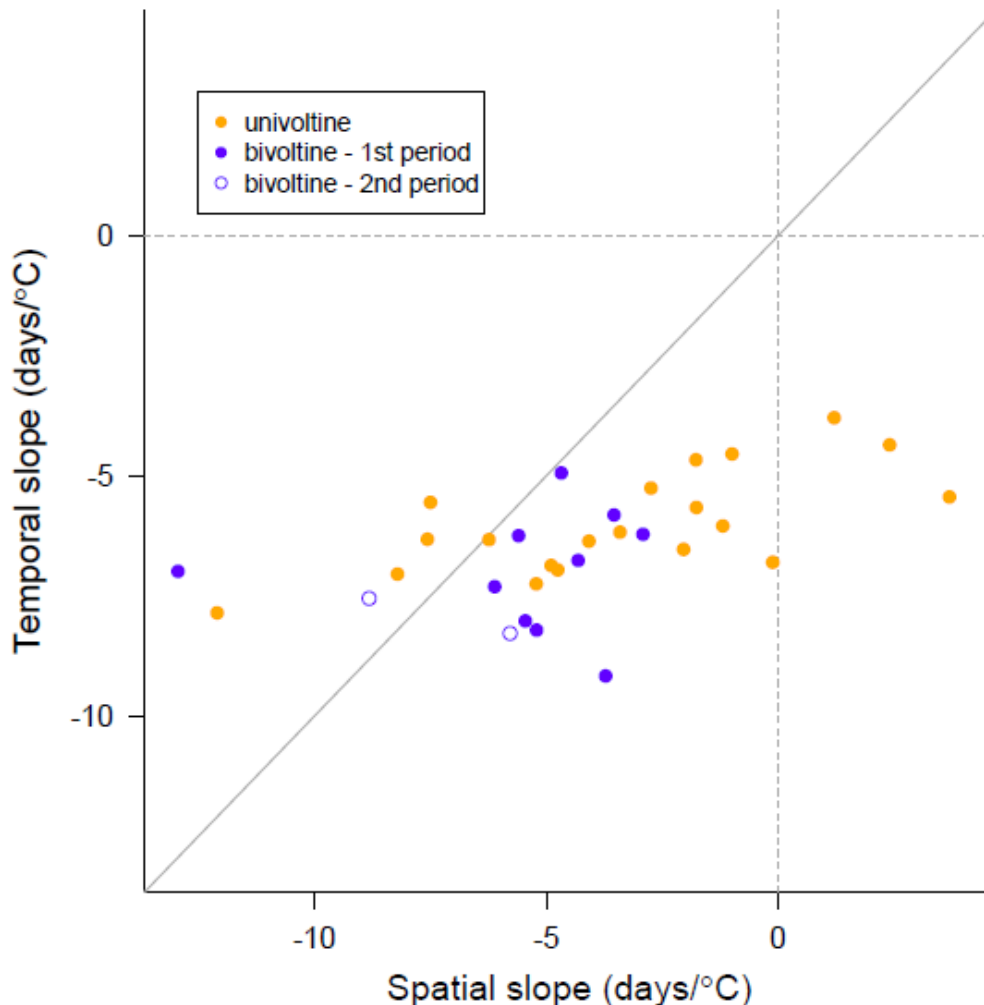In total 39/50 species (70%) show significant advances since 1976

Botham *et al.* (2008) *UKBMS Report*
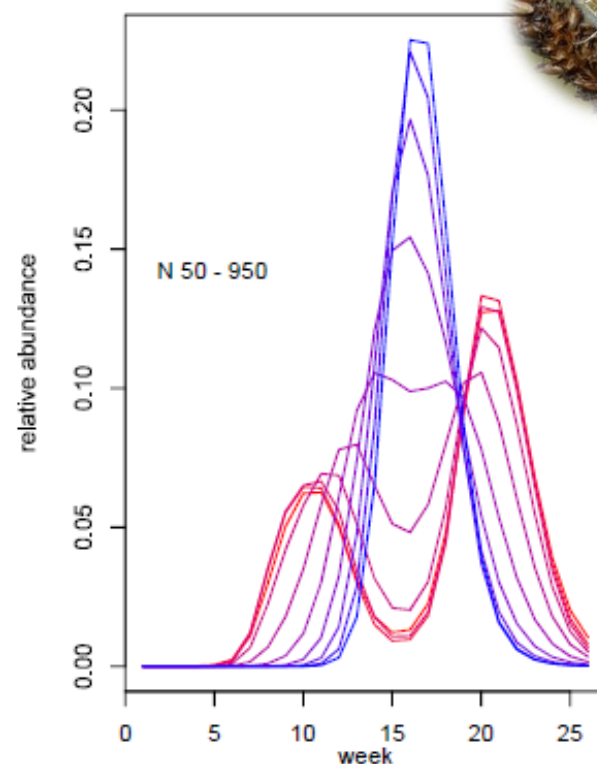
Hodgson et al. (2011) *Glob. Ch. Biol.*

Observed climate impacts: 1- **Phenology**

For a 1°C warming:

There is a greater shifts in flight date over time than over space

Potentially indicates local adaptation between sites

Roy et al. (2015) *Glob. Ch. Biol.*

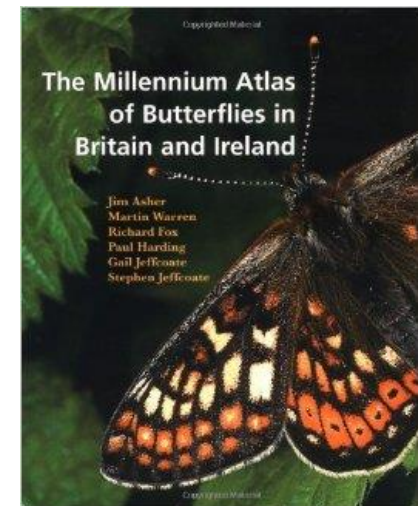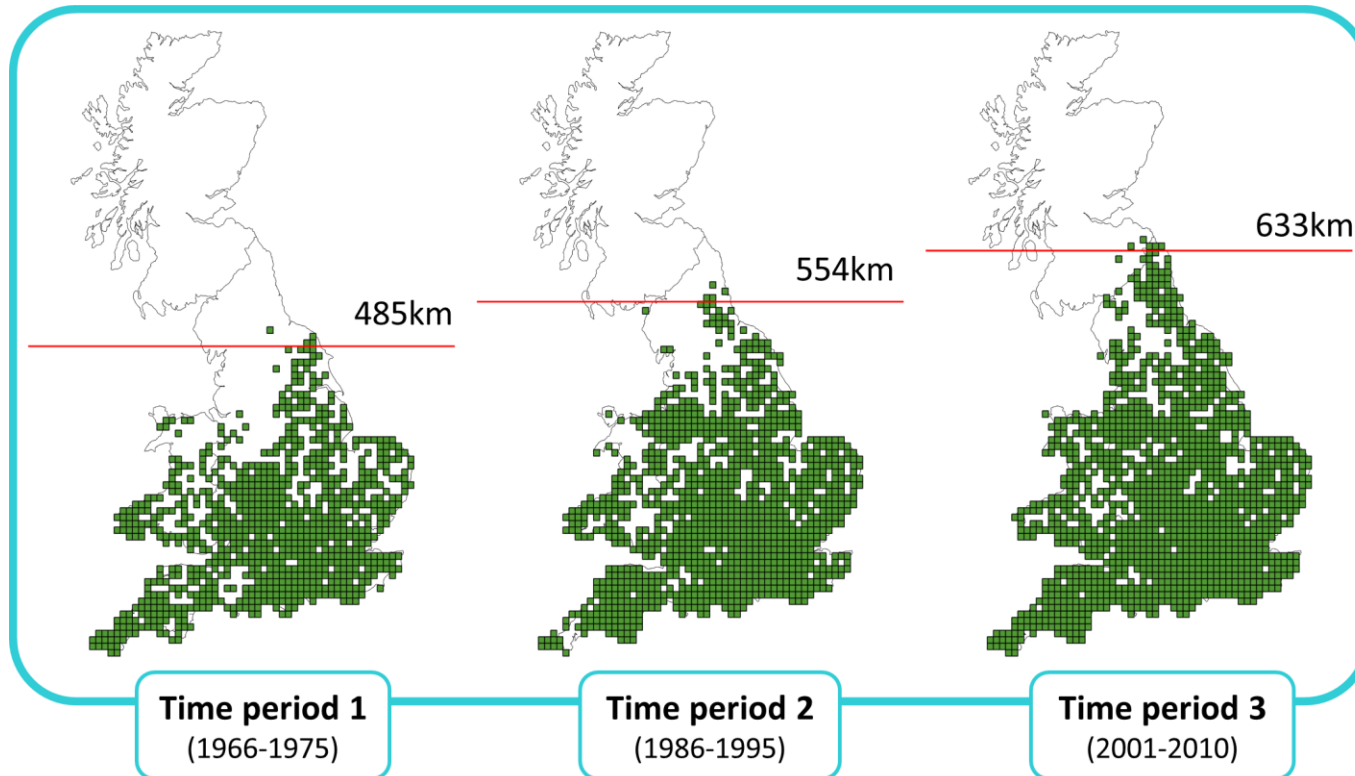# Observed climate impacts: 2- Range shifts

Many species are shifting their ranges northwards….
Around 20.5km decade^{-1} across all butterflies (= 5.6cm day^{-1})

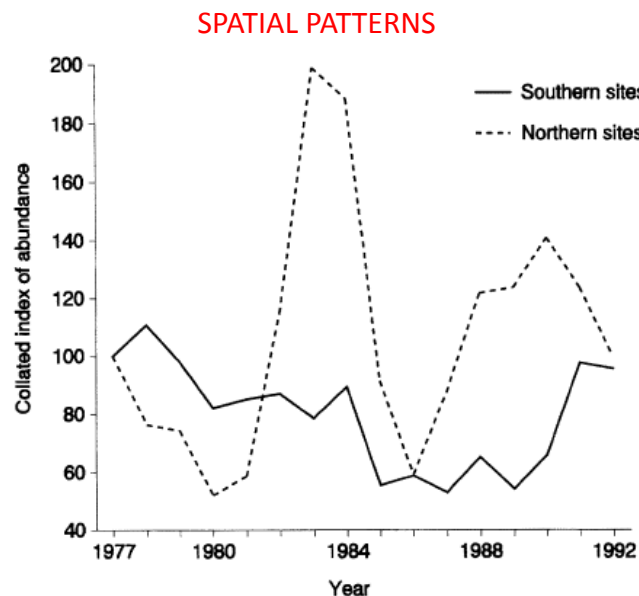Warren et al. (2001) *Nature*, Chen (2011) *Science*, Menéndez et al. (2006) *Proc Roy Soc B.*

Presence of
Thymelicus sylvestris
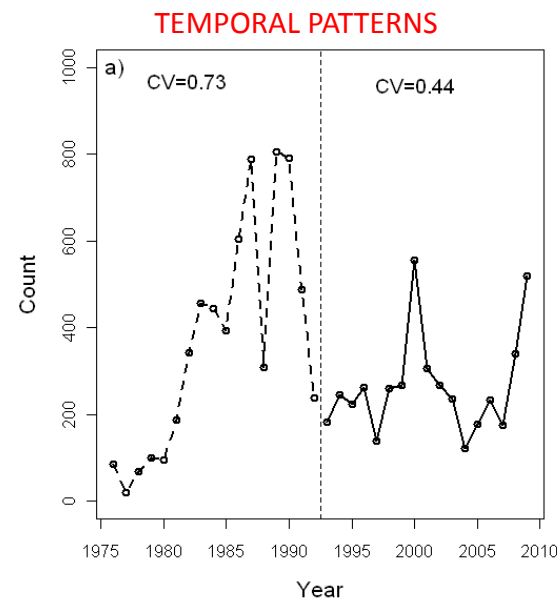Occupied 10km square
Northern range margin

633km

554km

485km

Time period 1
(1966-1975)

Time period 2
(1986-1995)

Time period 3
(2001-2010)

The Millennium Atlas of Butterflies in Britain and Ireland

Jim Asher
Martin Warren
Richard Fox
Paul Harding
Gail Jeffcoate
Stephen Jeffcoate

Mason *et al.* (2015) *Biol. J. Linn. Soc*

Observed climate impacts: 3- **Population dynamics**

- Theory and experiment show that variability is important for population persistence, i.e. stable populations have lower extinction risk (Inchausti & Halley, 2003, *J. Anim. Ecol.*; Pimm *et al.* 1988, *Am. Nat.*)

- Animal populations are thought to be more variable towards the edges of species ranges (Hansson & Hentonnen, 1985; Gaston, 2003)

- For example, butterflies populations showed increased fluctuations and synchrony at range edges (Thomas, Moss & Pollard, 1994; Oliver et al. 2014 *Ecography,* Powney et al. 2010*, Oikos*)

- Although these have dampened in recent decades (Oliver et al., 2012, *Glob. Ch. Biol.*)

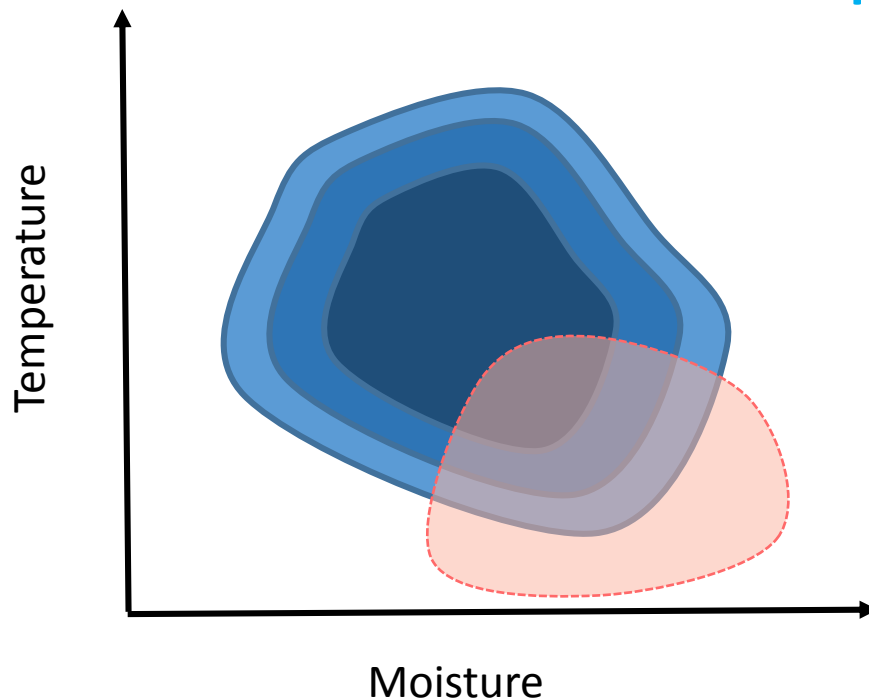SPATIAL PATTERNS   TEMPORAL PATTERNS

(Thomas, Moss & Pollard, *Ecography*, 1994)   (Oliver et al., 2012, *Glob. Ch. Biol.*))
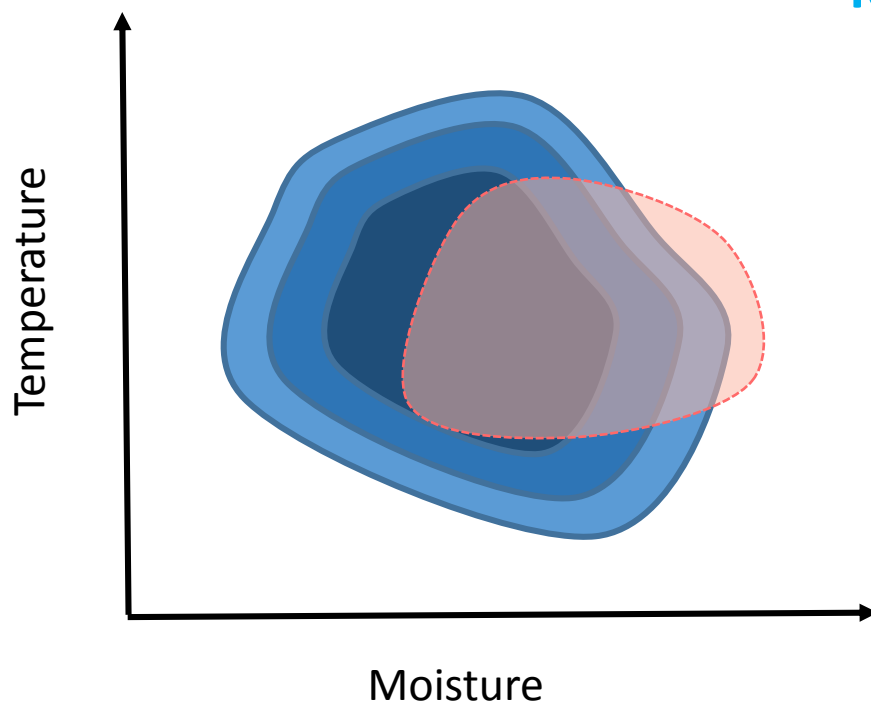
Fundamental niche: The set of environmental conditions in which populations can persist (Hutchinson 1957)

Towards the edge of the niche:

- Lower growth rates & smaller populations (Sagarin & Gaines, 2002 *Ecology Letters*)

- Narrower habitat breadth (Oliver et al. 2009 *Ecology Letters; Davies, 2006, J. Appl. Ecol.)*

- Higher population variability (Thomas et al, 1994, Ecography; Oliver et al 2012 *GCB*; Oliver et al, 2014 *Ecography*)

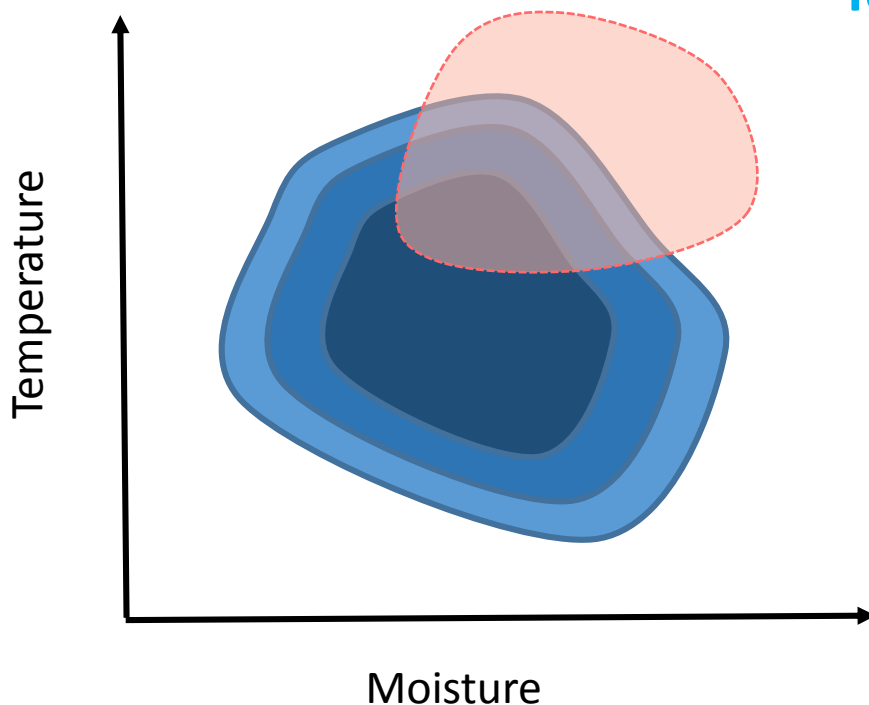- Higher population synchrony (i.e. correlated dynamics; Powney et al. 2010*, Oikos)*

Fundamental niche: The set of environmental conditions in which populations can persist (Hutchinson 1957)

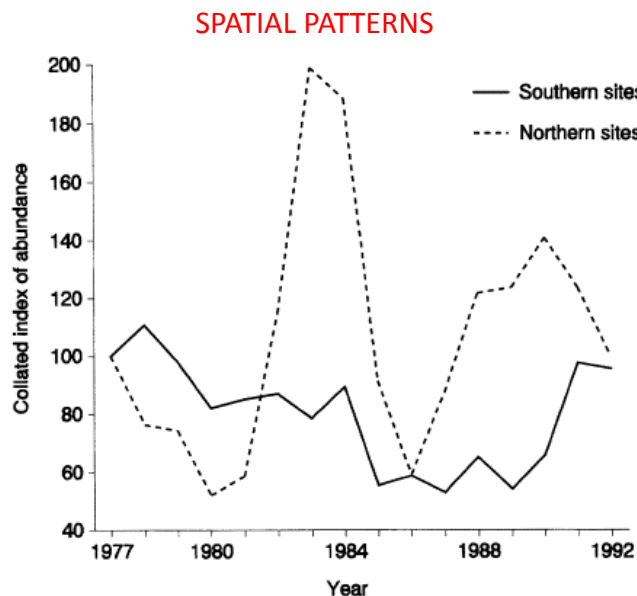

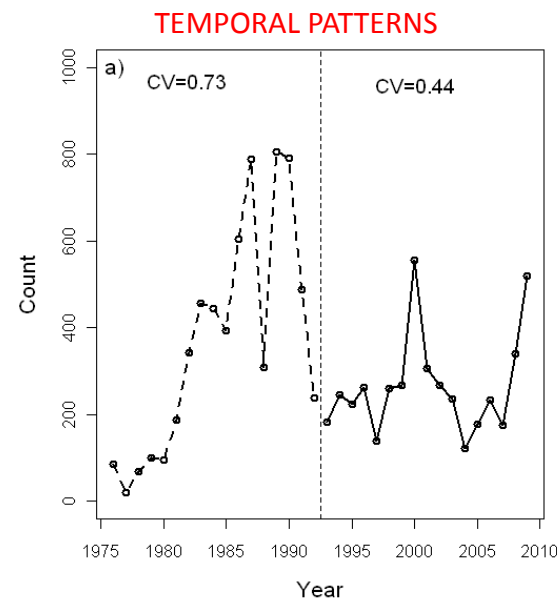Temperature (y-axis) vs Moisture (x-axis)

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SPATIAL PATTERNS

TEMPORAL PATTERNS

(Thomas, Moss & Pollard, *Ecography*, 1994)

(Oliver et al., 2012, *Glob. Ch. Biol*.))
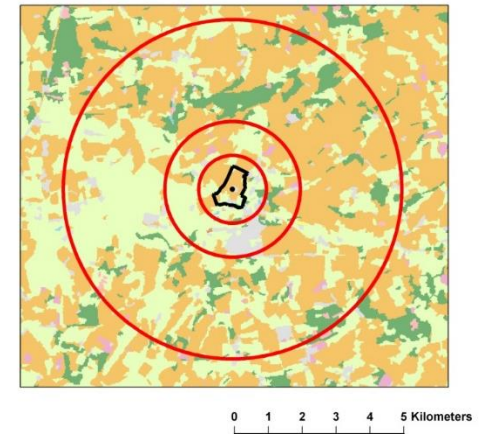
Observed climate impacts: 3- Population dynamics

Butterfly populations also show evidence of increased sensitivity to weather towards climatic range edges (Mills *et al.* accepted, *GEB)*
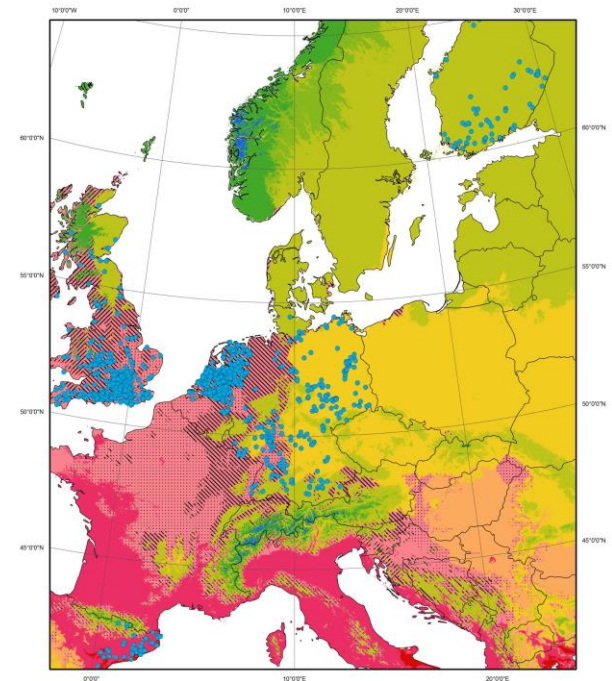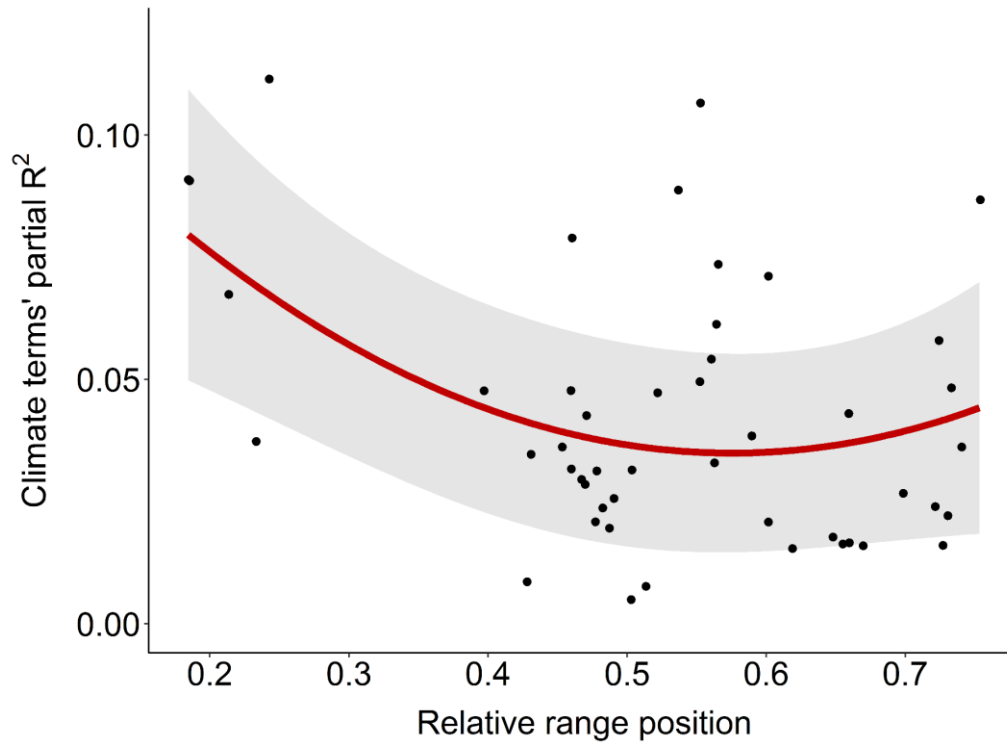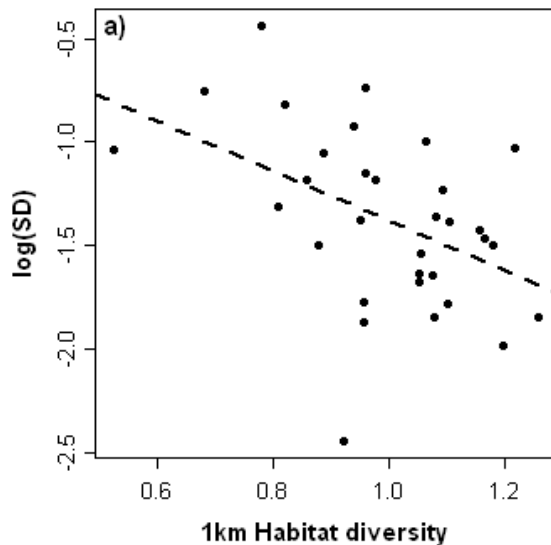
Observed climate impacts: 3- Population dynamics

Many species show lower variability in landscapes with higher habitat or topographic diversity
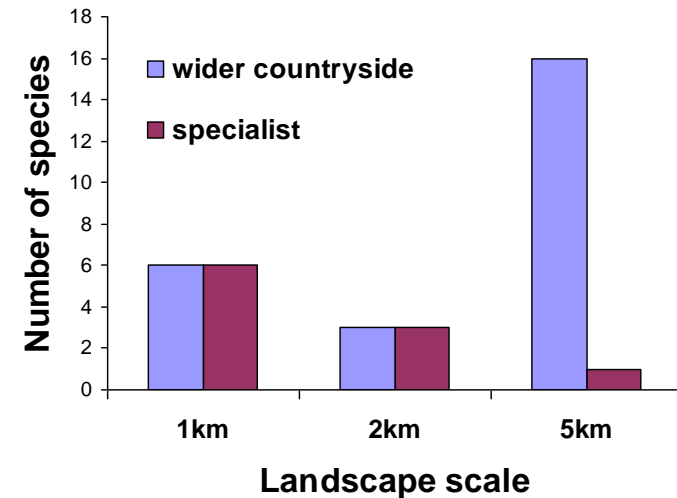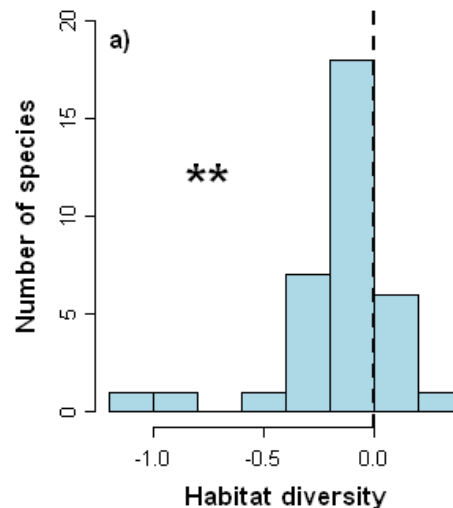
The most appropriate spatial scale to characterise landscape diversity differes between specialist and wider-countryside species

Oliver *et al.* (2010) *Ecol. Lett*
Oliver *et al.* (2014) *Ecography*
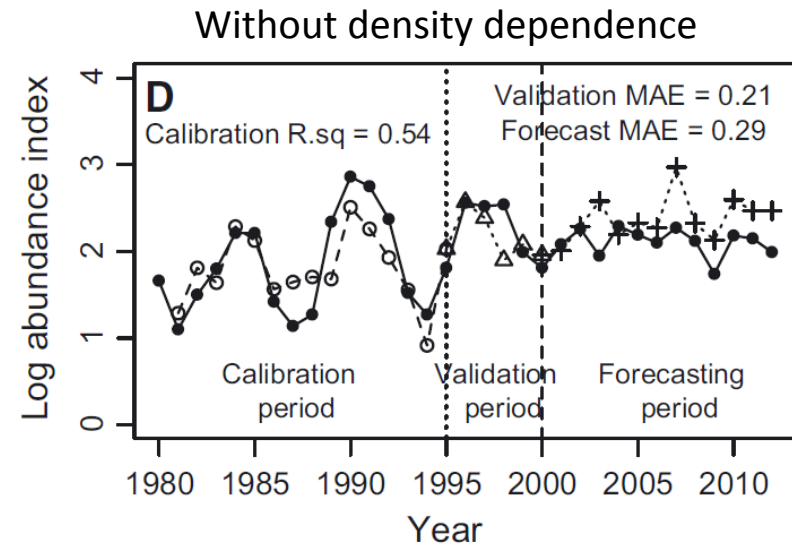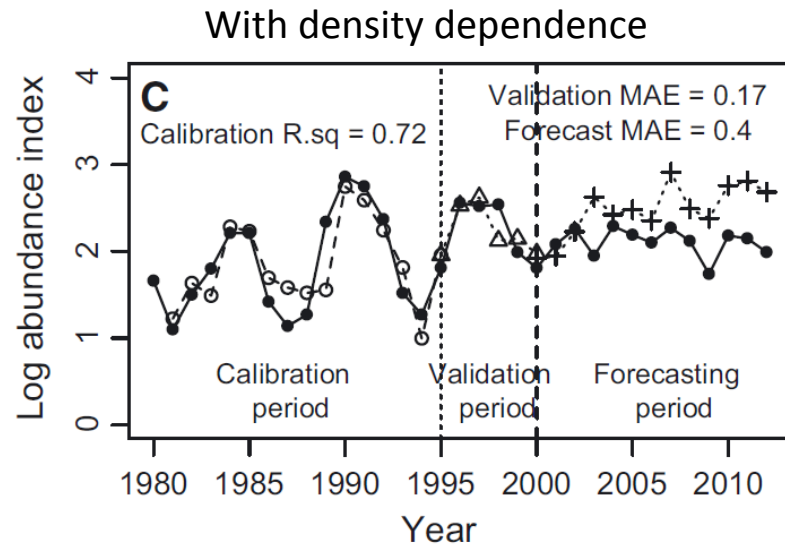
Observed impacts: 3b- Population dynamics

What are the key weather variables that influence population dynamics?
(Roy, 2000, *J. Appl. Ecol*; Wallis de Vries 2011 *Oecologia*)

Observed impacts: 3b- Population dynamics

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**Predictive population models for the Holly
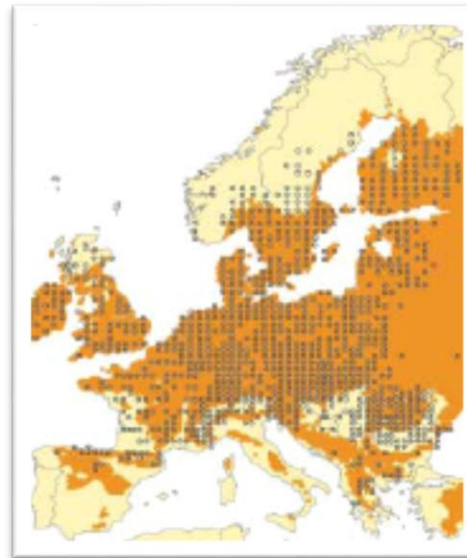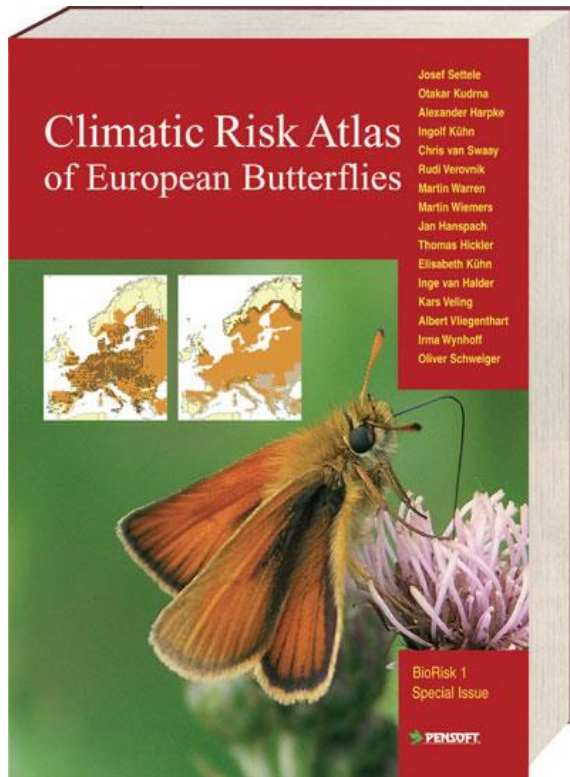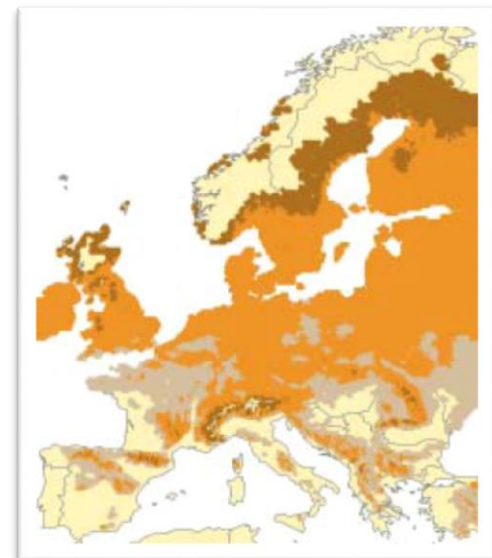Blue butterfly, *Celastrina argiolus***

With density dependence   Without density dependence

Driver: 🌦️ **and/or** 🐝 **?**

Revels (2006) *British Wildlife*; Oliver & Roy, (2015) *Biol. J. Linn. Soc*

Predicting future climate change impacts

e.g. Species distribution/ bioclimate modelling

CURRENT

BAMBU SCENARIO 2050

Climate change risk assessment
Commissioned by Natural England

| CONTROL FOR RECORDER EFFORT		SPECIES DISTRIBUTION MODELLING		CLIMATE CHANGE RISK ASSESSMENT
FRESCALO- Dyer et al. (2017) *J. Appl. Ecol.* Fox et al. (2014) *J. Appl. Ecol.* Hill (2011) *MEE*	**+**	Beale et al. (2014) *MEE*	**+**	Thomas et al (2012) *MEE* Oliver et al. *(2012) J. Appl Ecol.; (2016) Biol. Cons.*
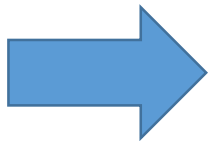
➡ Risk assessment for 3,048 English species across 17 taxonomic groups

Pearce-Higgins et al. (2017) A national-scale assessment of species distributions and climate change: implications of changing distributions for future conservation. *Biol. Cons.*

# Climate change risk assessment
Commissioned by Natural England
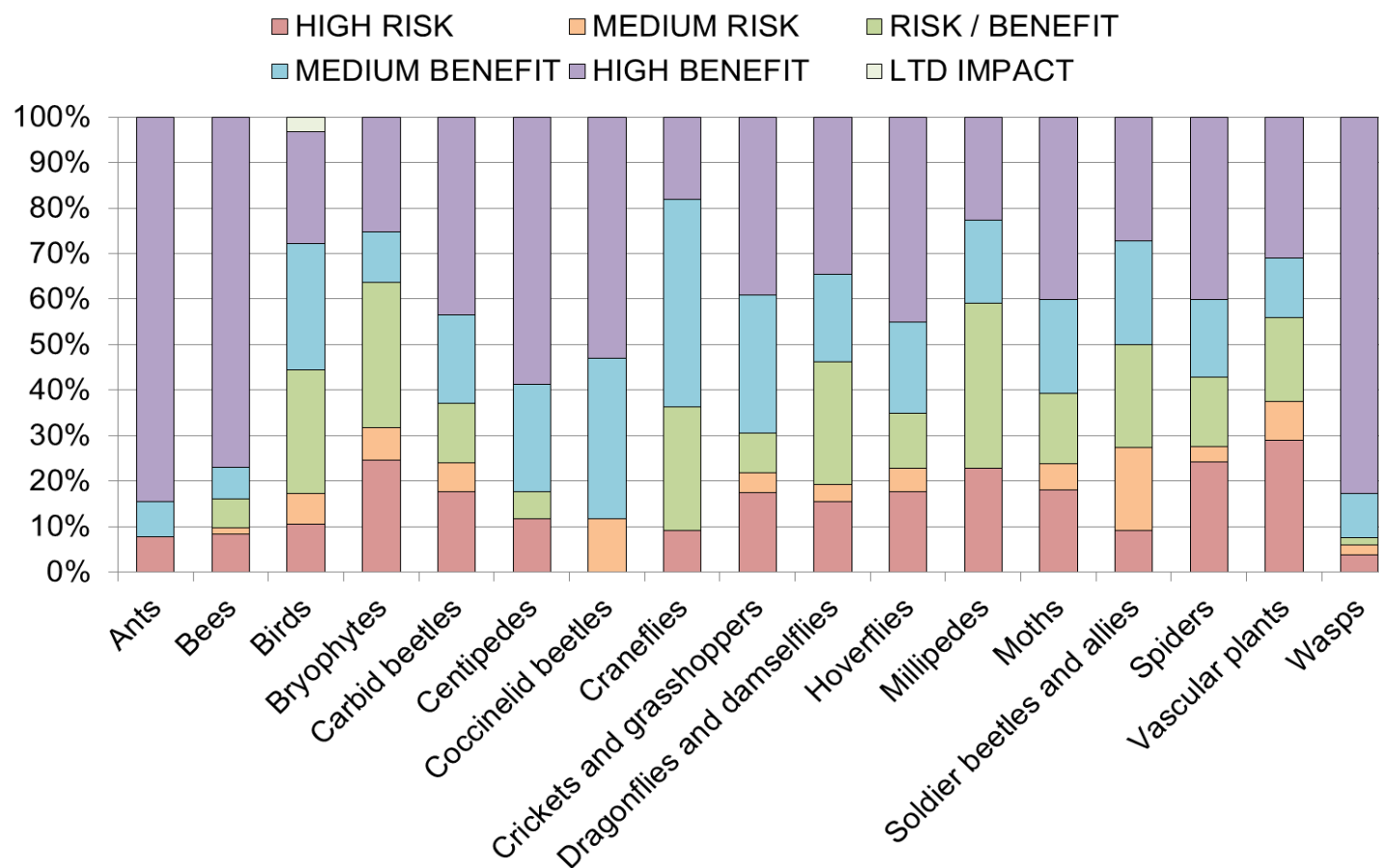
Pearce-Higgins et al. (2017) A national-scale assessment of species distributions and climate change: implications of changing distributions for future conservation. *Biol. Cons.*

Climate change

Warming of the climate system is *unequivocal*, and since the 1950s, many of the observed changes are *unprecedented* over decades to millennia
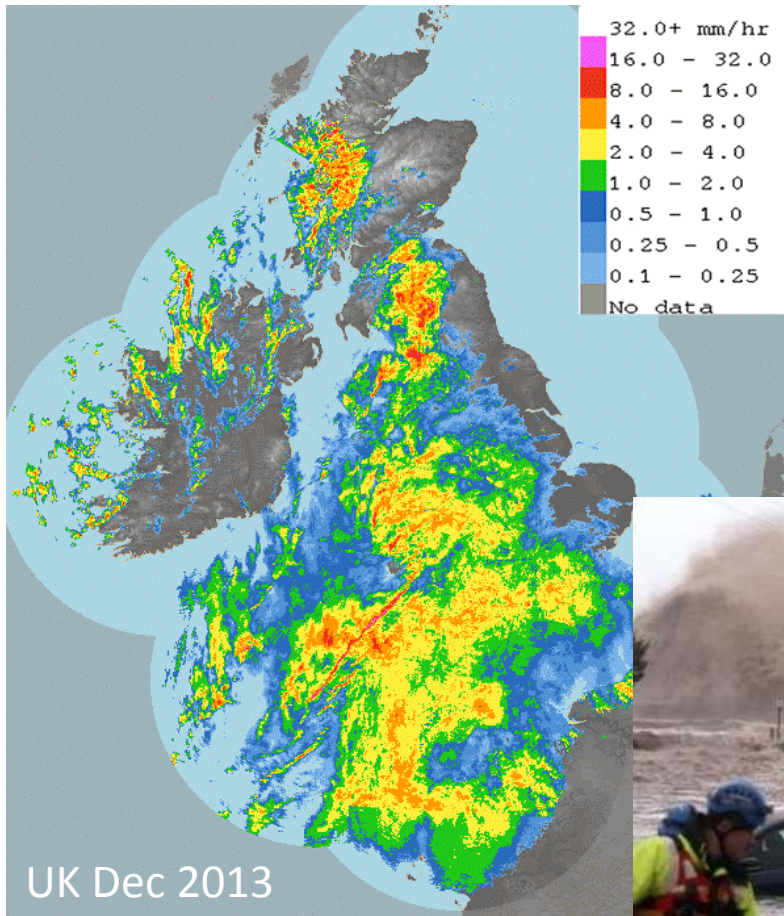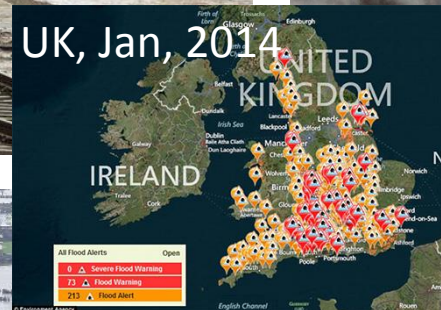

IPCC projected long-term changes in climatic means

IPCC, 2013: Summary for Policymakers
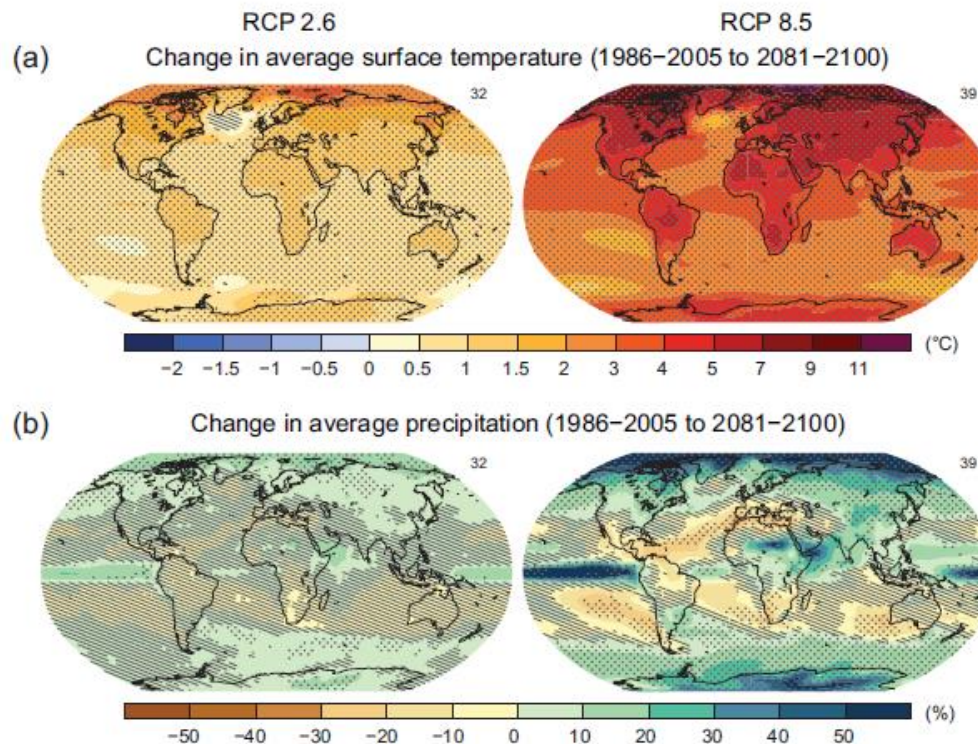
Climate change

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It is *virtually certain* that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is *very likely* that heat waves will occur with a higher frequency and duration
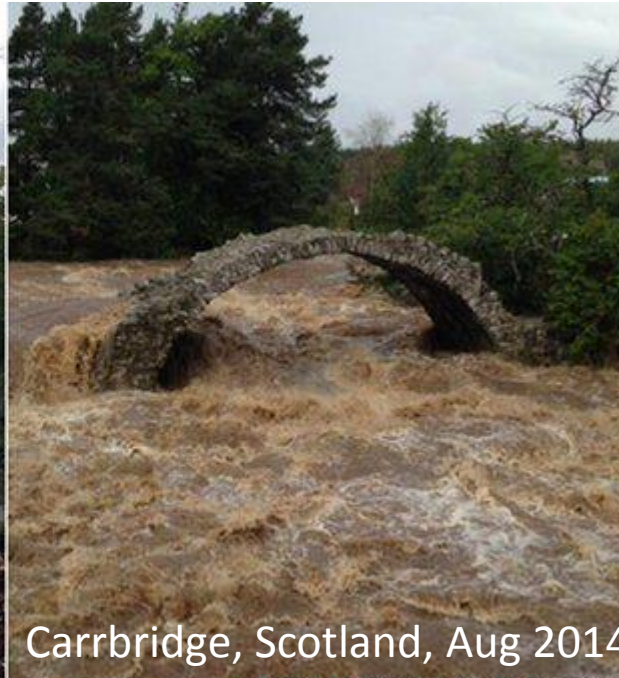
IPCC, 2013: Summary for Policymakers

UK extreme weather 2013

UK Dec 2013

Lincoln Dec 2013

N. Wales Dec 2013

County Down, Ireland, Dec 2013

UK extreme weather 2014

Devon Feb 2014

UK, Jan, 2014

Somerset Feb 2014

Cornwall Feb 2014

UK extreme weather 2014

Carrbridge, Scotland, Aug 2014
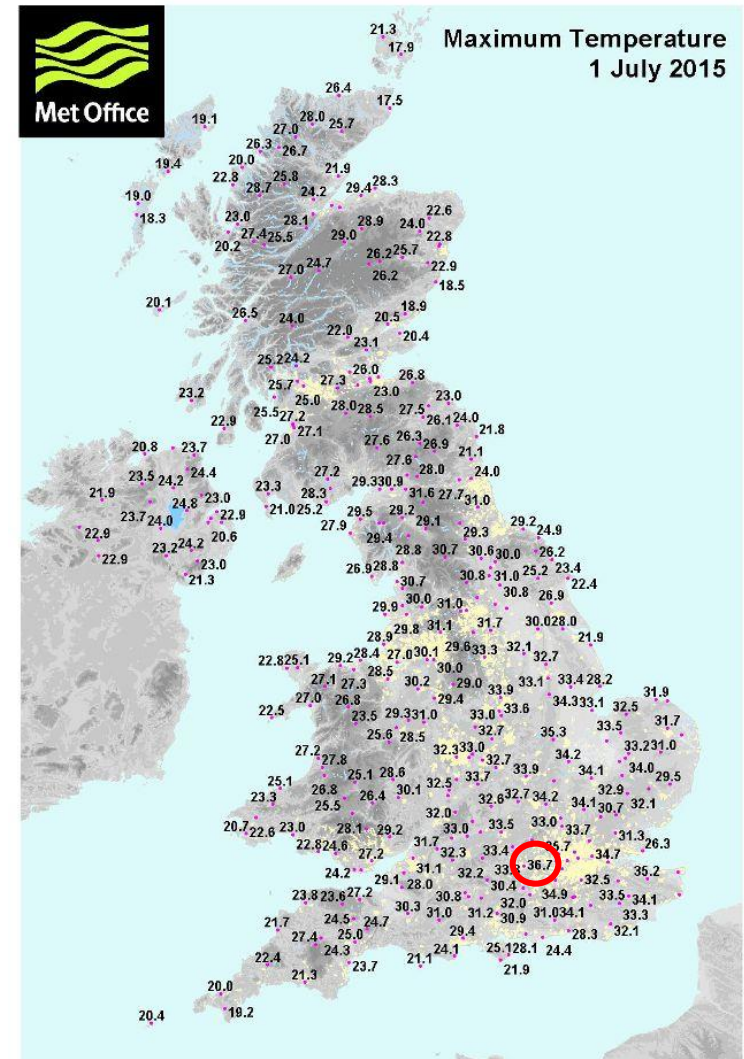
Ullapool, Scotland, Aug 2014

Moray, Scotland, Aug 2014

UK extreme weather 2015
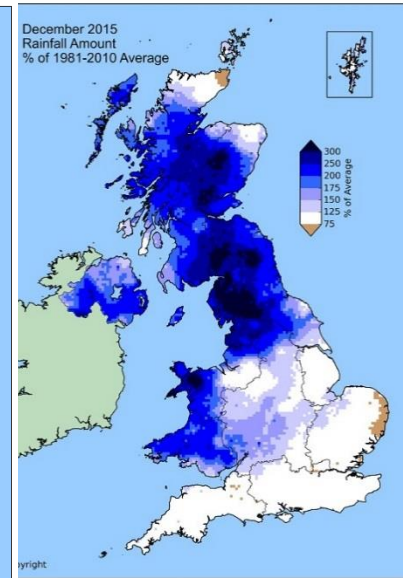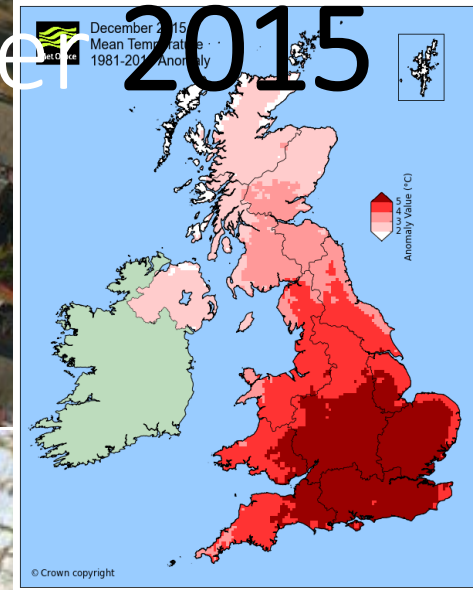

Skegness, July 2015

Wimbledon, July 2015

University of Reading

UK extreme weather 2015

Cumbria, Dec 2015

Bury, Dec 2015

Newhaven, Dec 2015

Carlisle, Dec 2015

December 2015
Mean Temperature
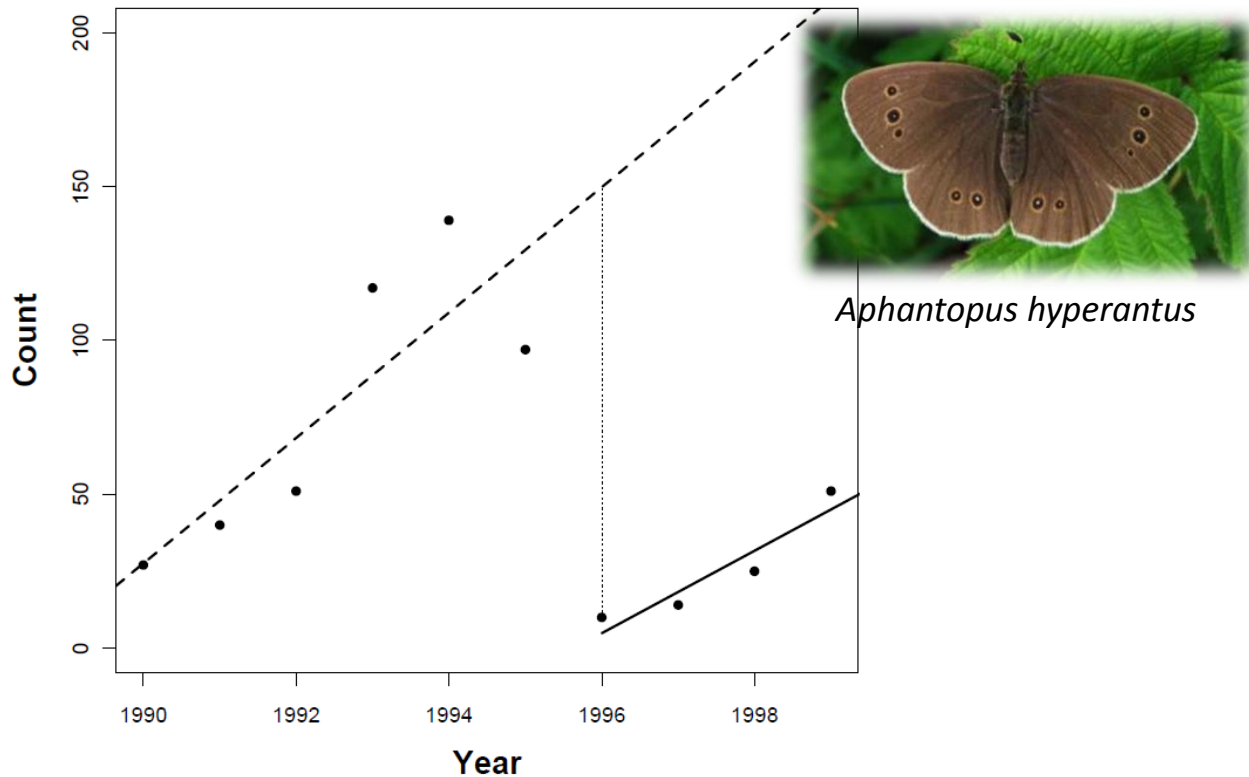1981-2010 Anomaly

December 2015
Rainfall Amount
% of 1981-2010 Average

2016...2017...2018?

(and the impacts of these altered conditions on wildlife?)

Predictions using detailed analysis of monitoring data

- 1995 drought event in the UK
- Many plant and insect species negatively affected (Morecroft et al., 2002, *GEB*)
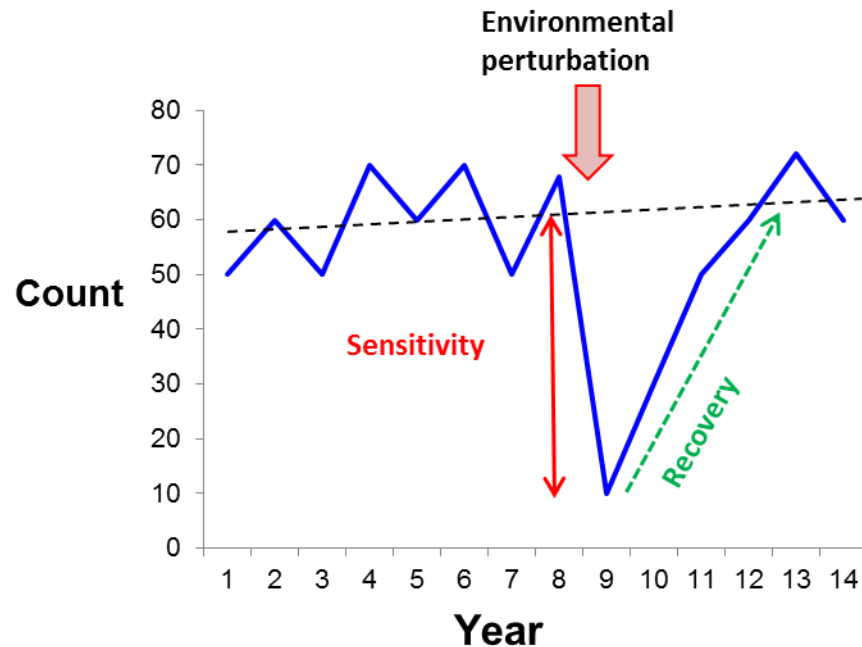

Aphantopus hyperantus

Most Ringlet populations (84%) crashed following the 1995 drought
(shown is an example from a single site)

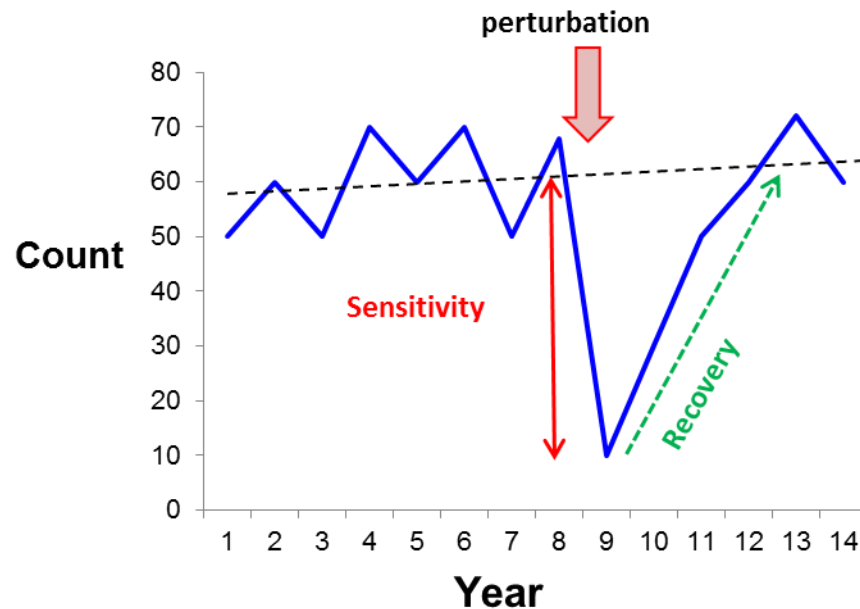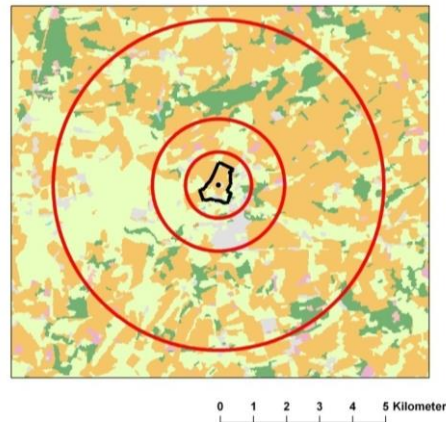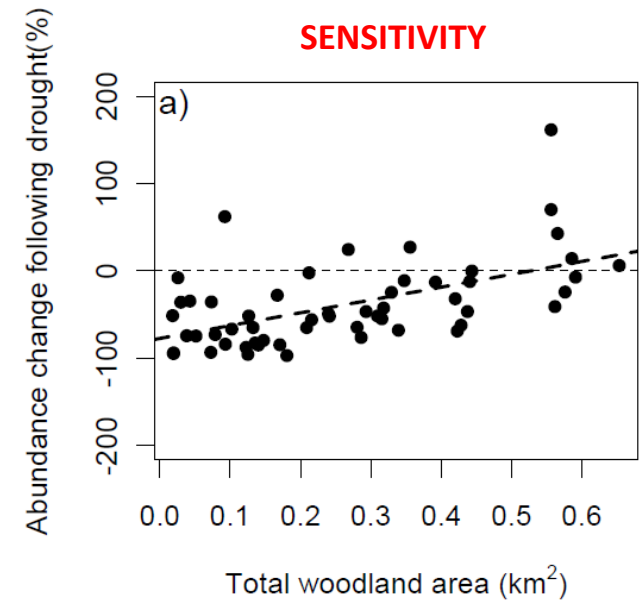# Predictions using detailed analysis of monitoring data

Aphantopus hyperantus

(Oliver, Brereton & Roy. 2013, *Ecography*)

Predictions using detailed analysis of monitoring data

Aphantopus hyperantus

(Oliver, Brereton & Roy. 2013, *Ecography*)

Predictions using detailed analysis of monitoring data

Aphantopus hyperantus

(Oliver, Brereton & Roy. 2013, *Ecography*)
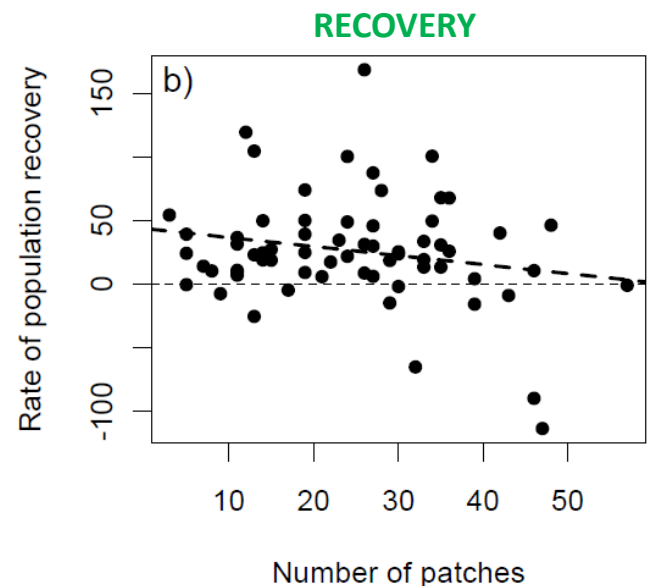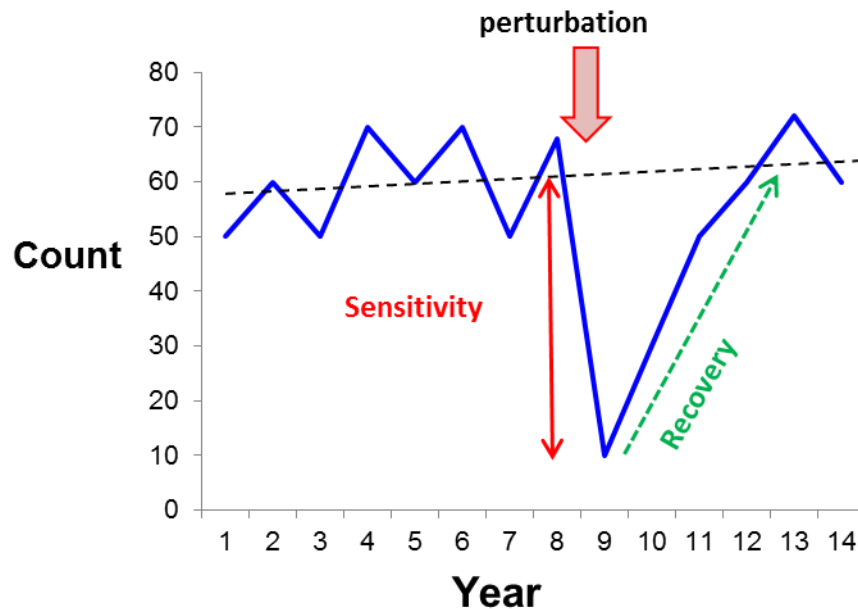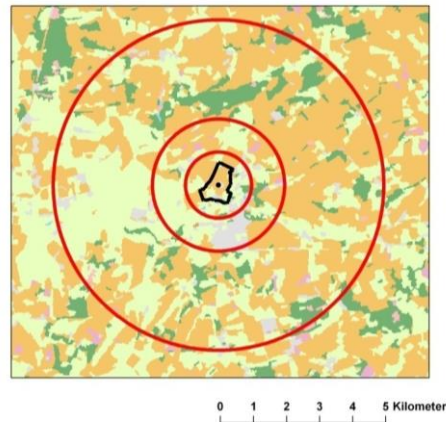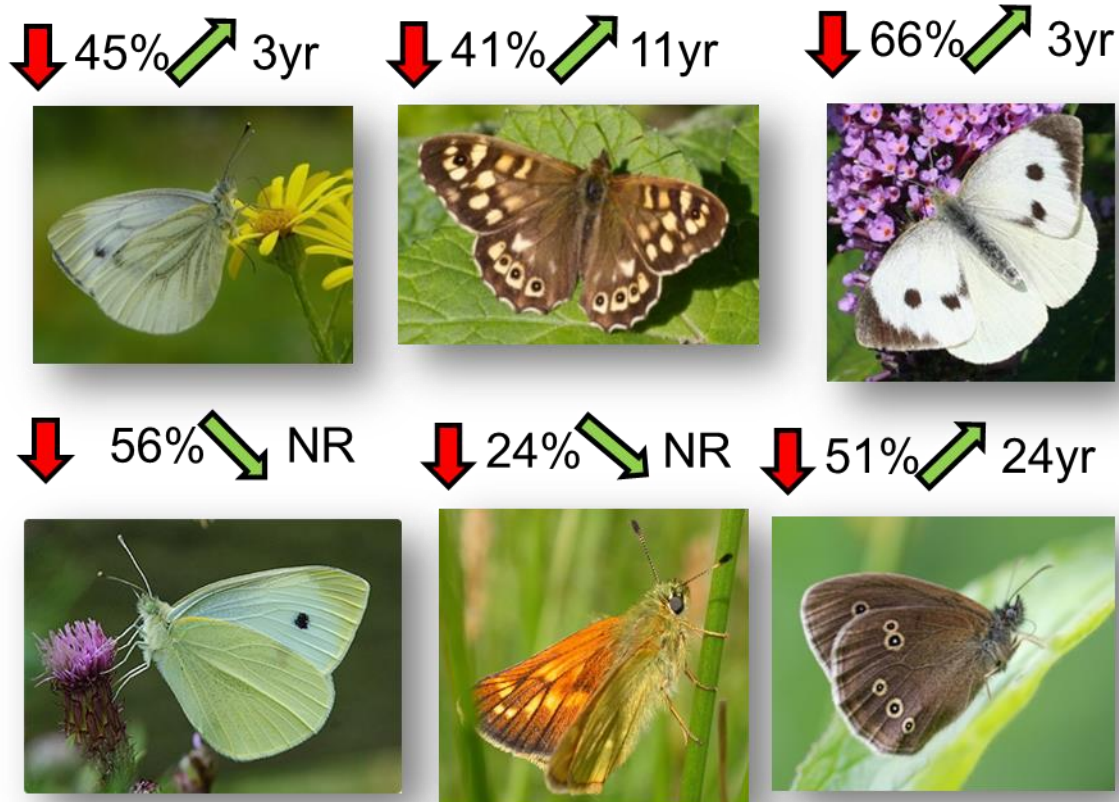
# Predictions using detailed analysis of monitoring data

- Analysis of six butterfly species identified as particularly drought sensitive
- Projected population persistence under increased drought frequency and under four different land use scenarios

Oliver et al. (2015) *Nature Climate Change* 5, 941–945.

Predicted changes in summer aridity

Central England- Projected changes in summer aridity
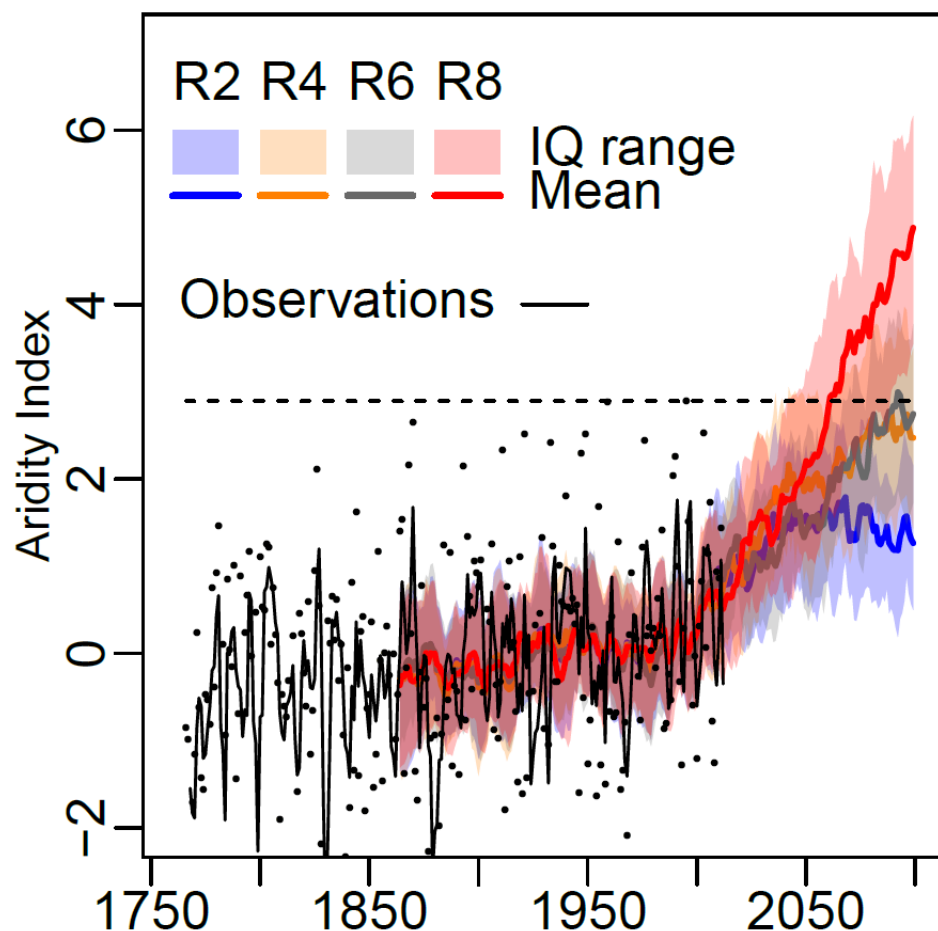
Four RCP emissions scenarios

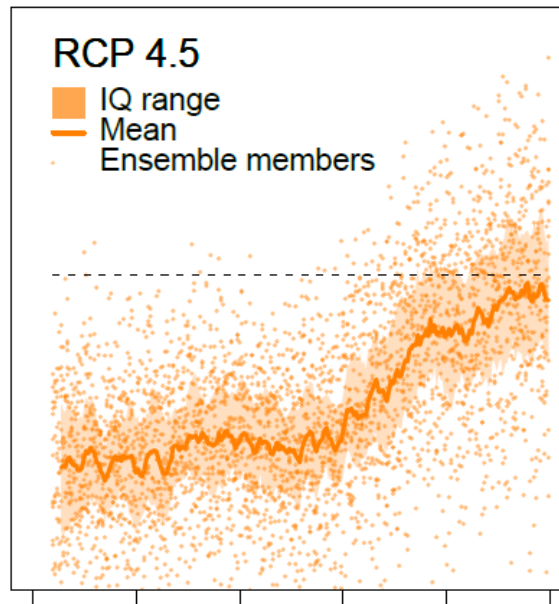17 Global Circulation Models from
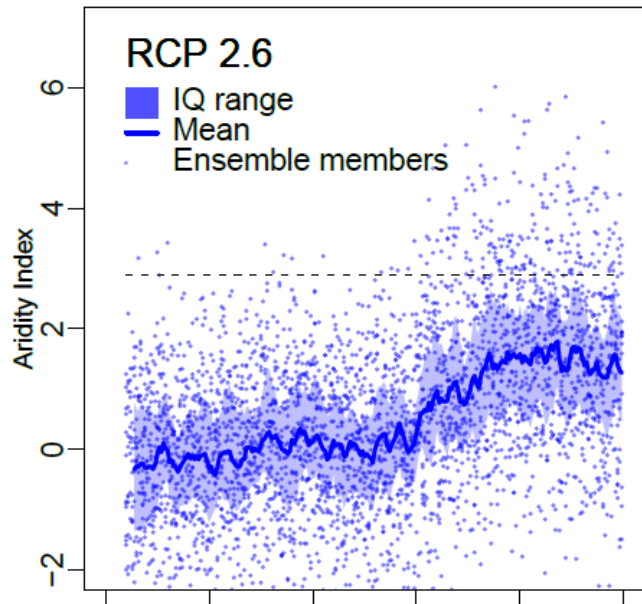IPCC CMIP5 database (2014)

1995 observed aridity

Aridity index =
$-(P_i-P)/\sigma+0.5(T_i-T)/\sigma$
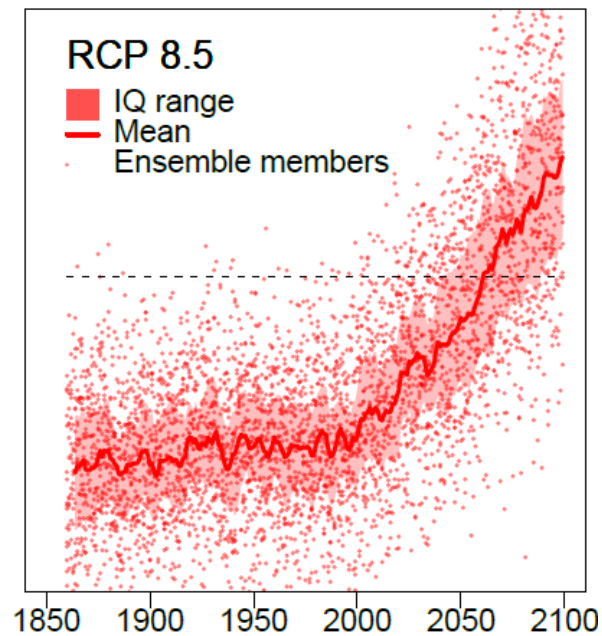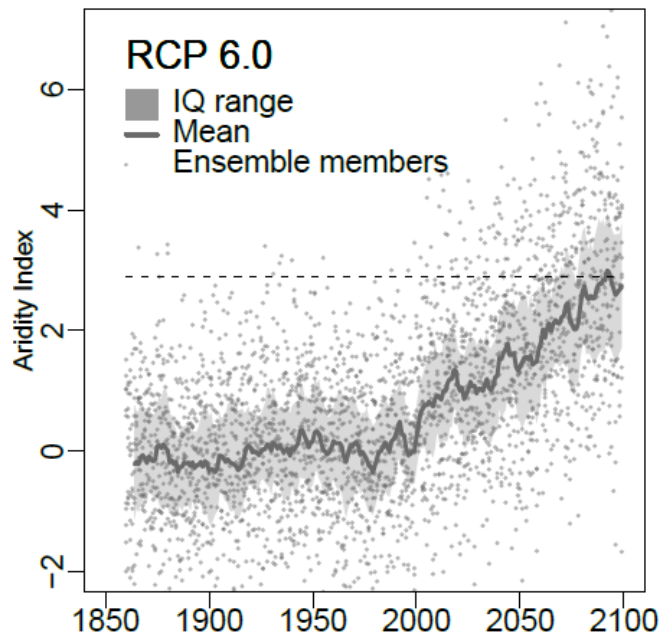
(Marsh et al, 2004, *Weather*)

Oliver et al. (2015)
Nature Climate Change
5, 941–945.

Projected changes in summer aridity

Predictions using detailed analysis of monitoring data
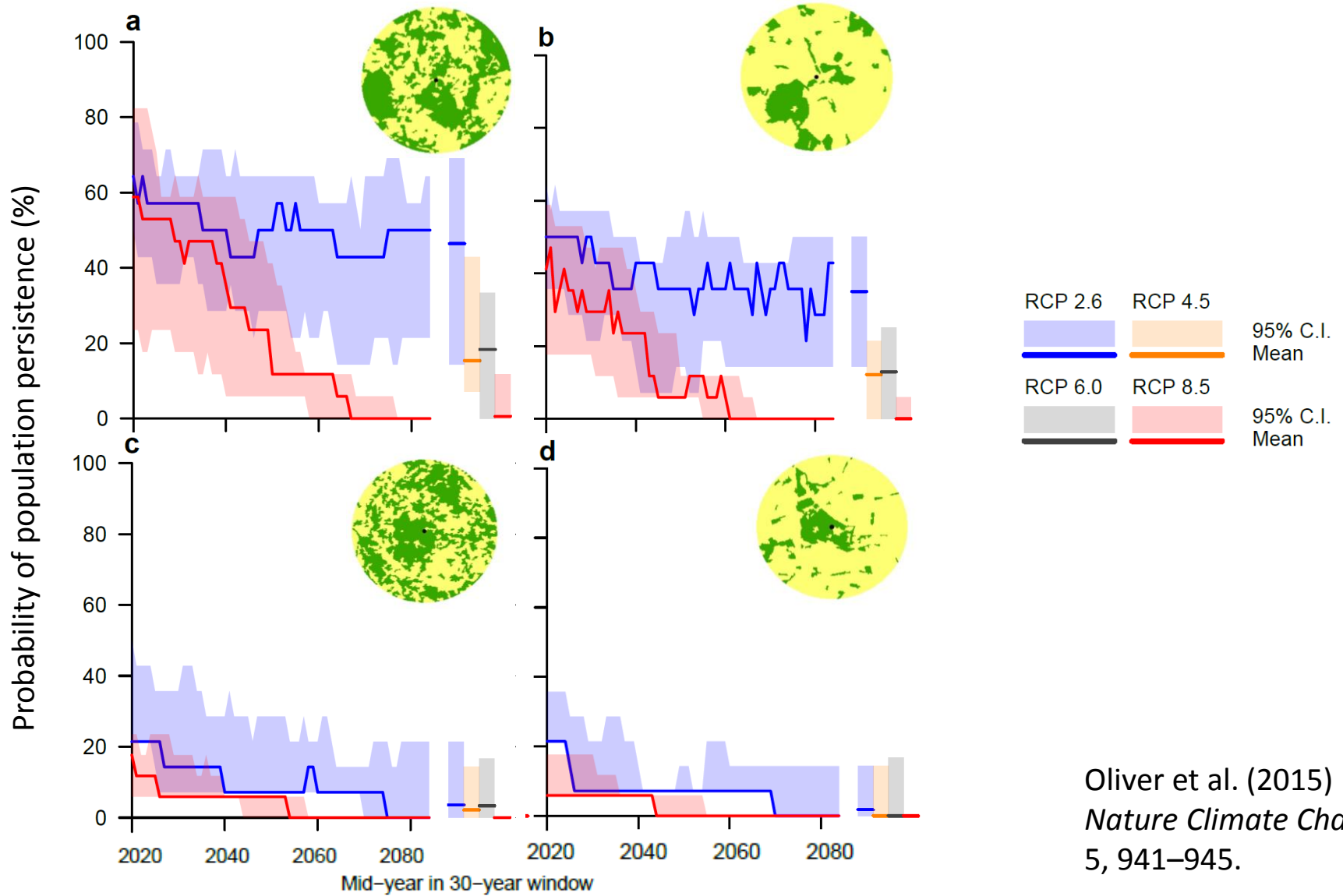
Oliver et al. (2015)
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"*The findings of studies like these are now being incorporated into the Climate Change Adaptation Manual (see article in the Sharing our Evidence section), as well as influencing our strategic thinking, for example on where to prioritise habitat creation.*"

Natural England Chief Scientist's Report 2015-16

www.gov.uk/natural-england

Summary so far:

1. Land use interactions with climate present additional risks, but also opportunities for climate change adaptation

2. Incorporating population dynamics into projections is crucially important and can lead to very different predictions of persistence

3. Long term population monitoring data are essential for informing environmental management under climate change!

Non-linear responses to drought
Impacts of the 1976 drought on butterflies

Was 1976 a 'tipping point' for butterflies?
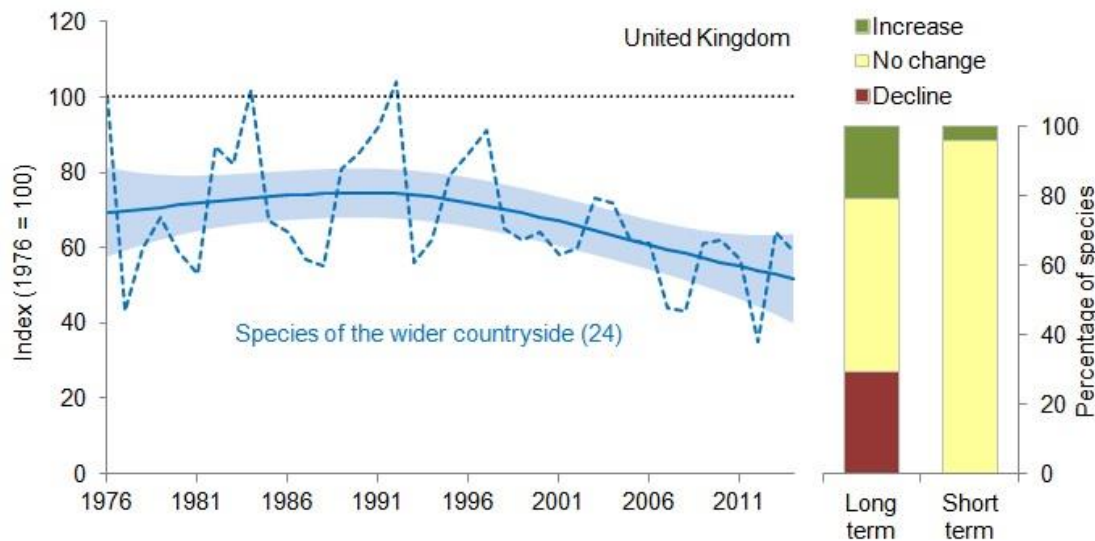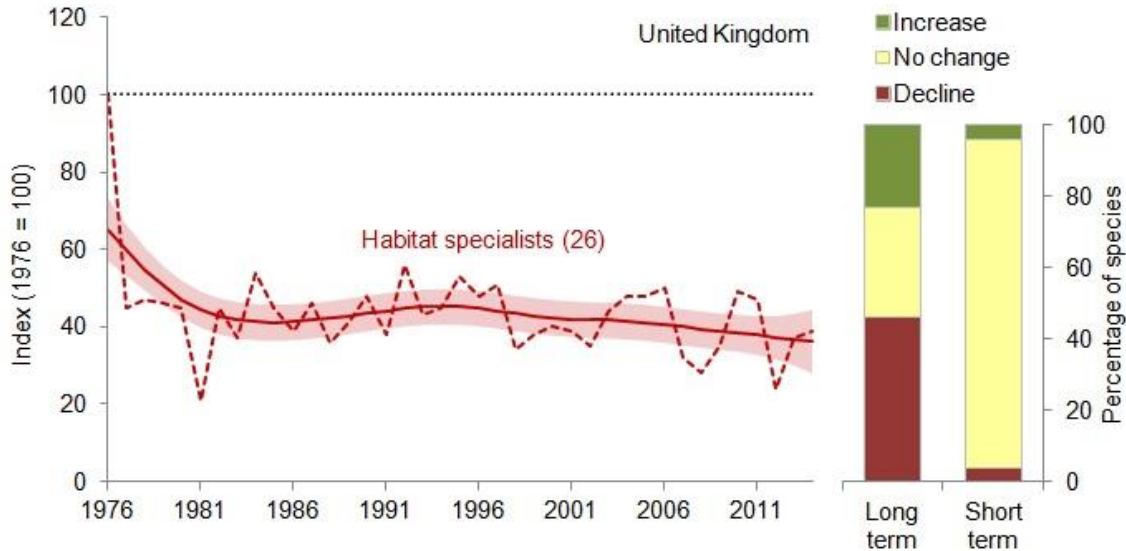
Was 1976 a tipping point for butterflies?

Abundance proxy from occurrence data

Habitat specialists

Wider countryside species
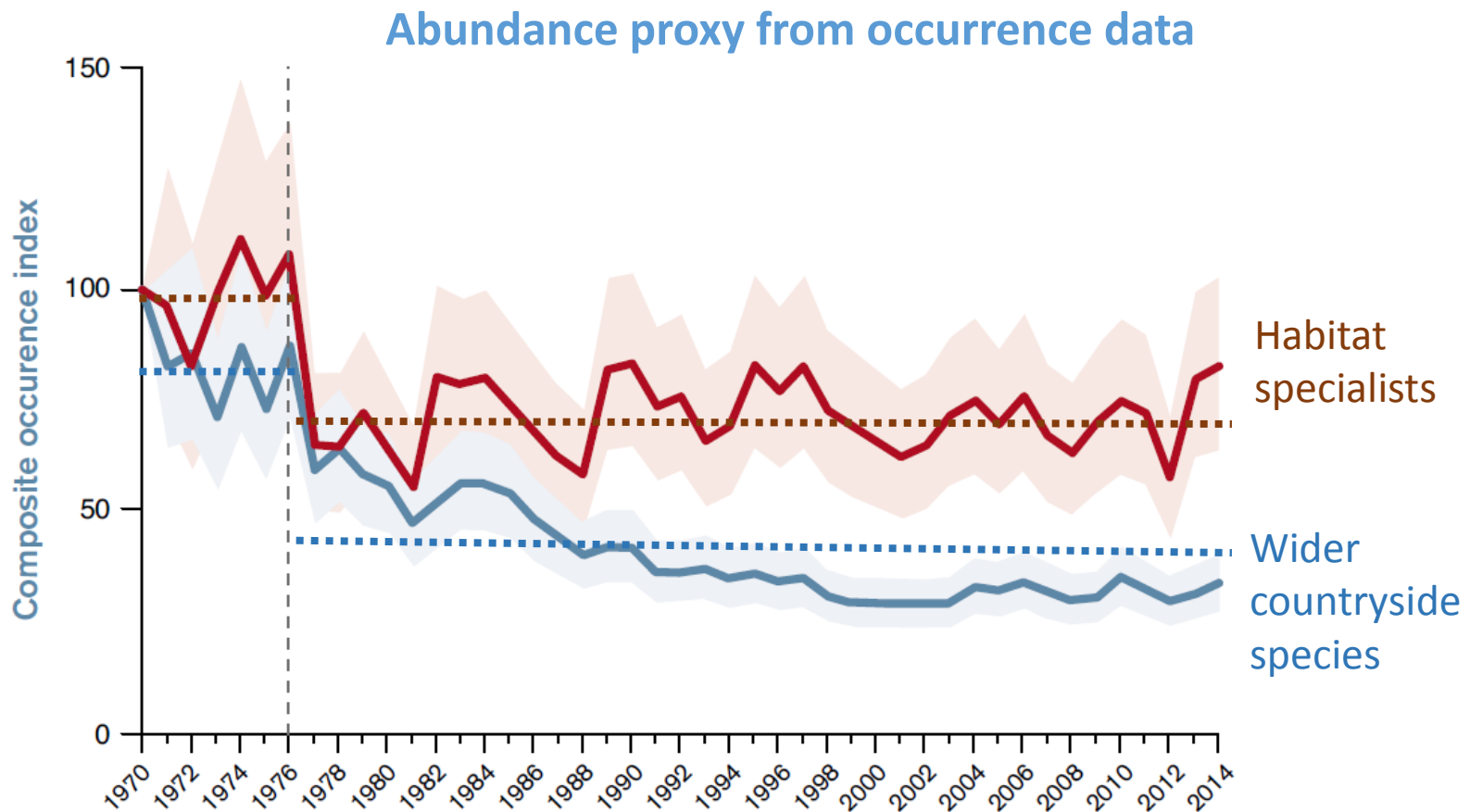
When indicators of state alone are not sufficient

The DPSIR framework:

| Drivers POPULATION GROWTH | → | Pressures FOOD PRODUCTION | → | State LOSS OF SPECIES | → | Impacts REDUCED HUMAN WELLBEING |

Response CONSERVATION POLICY
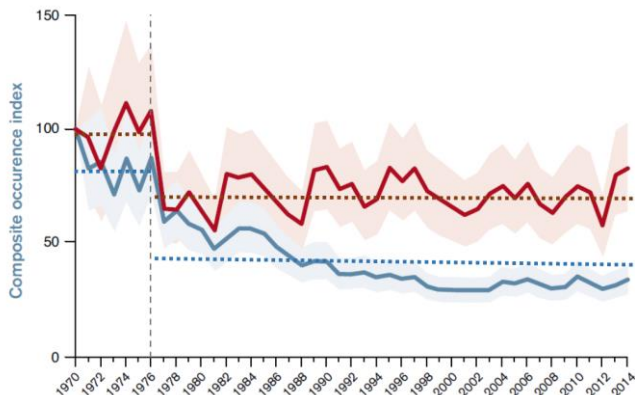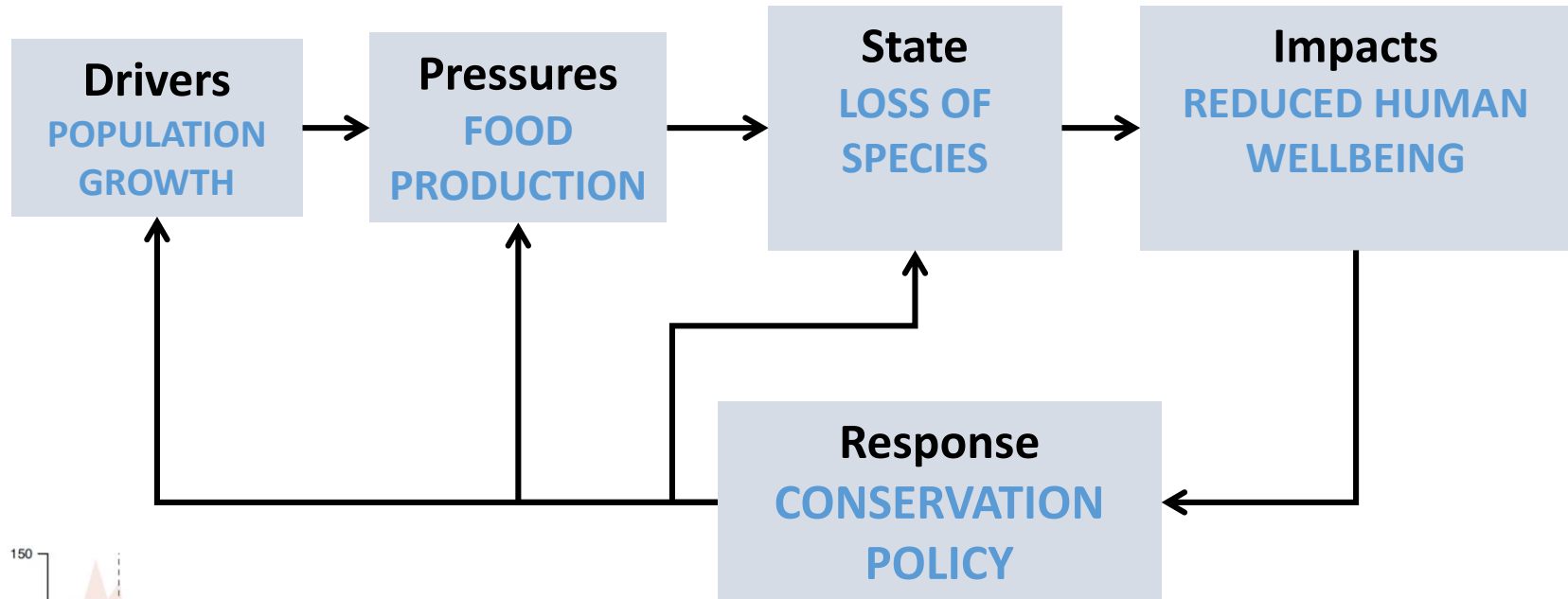
Do we also need **indicators of risk**?

Indicators of risk allow pro-active management responses

Key factors reducing risk to species:

- Habitat connectivity

(Powney 2011, MEE, Powney et al. 2012)

- Habitat heterogeneity

(Oliver et al, 2010 Ecol. Let)

- Genetic Diversity...

JNCC Habitat Connectivity Indicator C2

Landscape structure

Oliver et al. (2015) Biodiversity and the resilience of ecosystem functions *TREE*
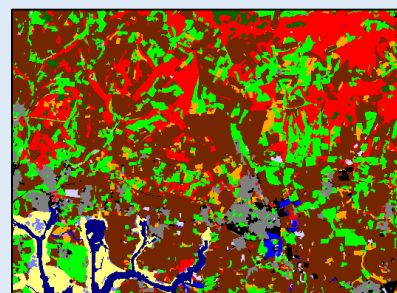
The key role of monitoring

Monitoring is essential for detecting and responding to climate change impacts :

IMPACT

- Phenology
- Range shifts
- Population dynamics
- Responses to weather

INTERVENTION

Informing habitat management and landscape management

OUTCOME

- Reduced phenological mismatch
- Facilitating range expansions
- Promoting stable persistent populations
- Reducing extreme weather impacts
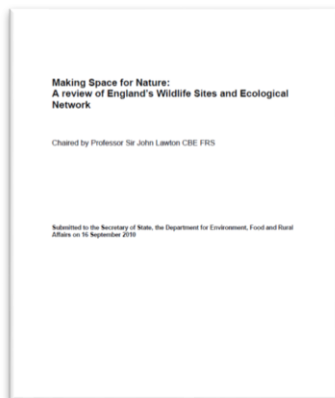
What next for butterfly monitoring?

Adapted from van Swaay
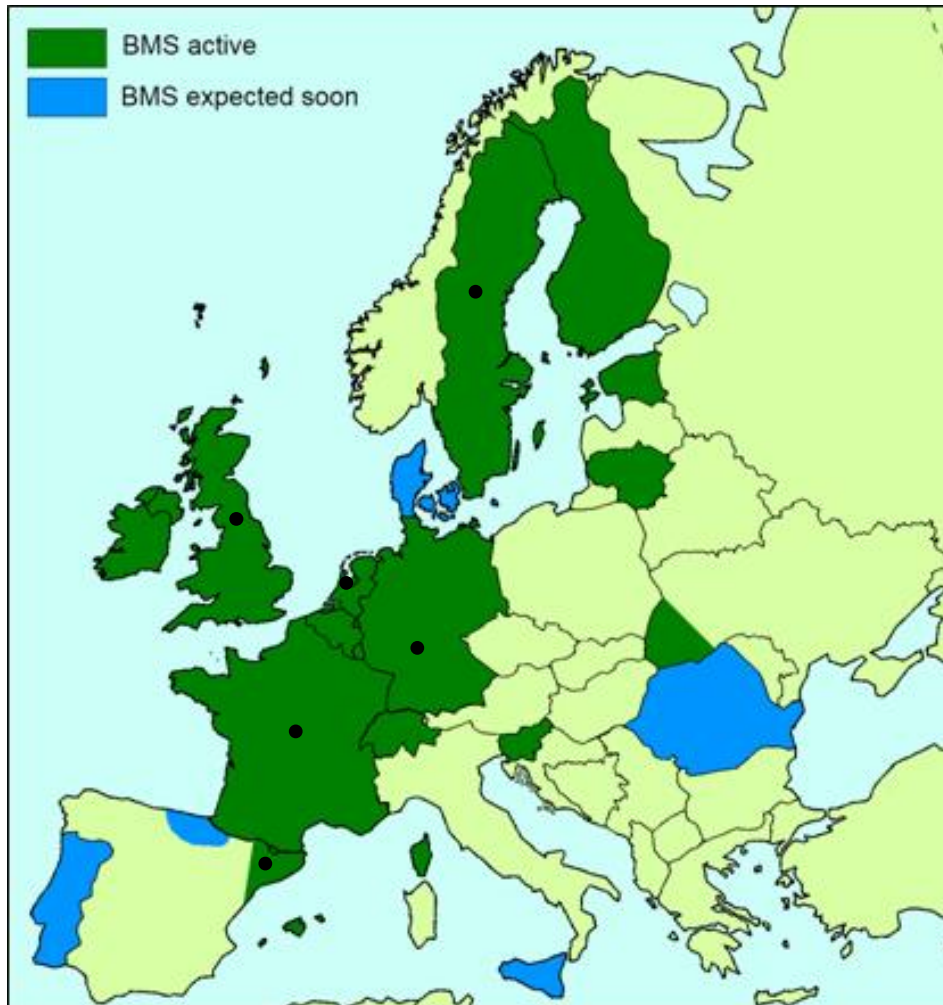
Optimising population monitoring methodology and scheme design:

- Dennis et al. (2013) *MEE*
- Roy et al. (2007) *J. Appl. Ecol*
- Schmucki et al. (2016) *J. Appl. Ecol.*

European scale analyses (e.g. Mills et al., GEB)

An indicator of genetic diversity

Developing a butterfly genetic monitoring scheme:

Model species: Meadow Brown *Maniola jurtina*
Method: Microsatellite markers developed
Locations: 15 long-term abundance monitoring sites with samples collected for 4 years
Plans: PhD student Matt Greenwell will pilot extension of sampling across Europe

Butterfly GEnetics Monitoring Scheme (BGEMS): 2020 pilot study
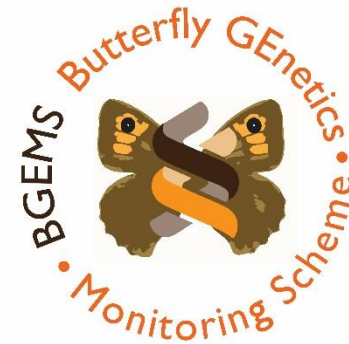
http://www.butterfly-monitoring.net/project/butterfly-genetics-monitoring-scheme-bgems-2020-pilot-study

An indicator of genetic diversity

Convention for Biodiversity 2020 targets:

Convention on Biological Diversity

Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use

Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services

Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

Butterfly population Genetics Monitoring Scheme (BGEMS)- pilot study
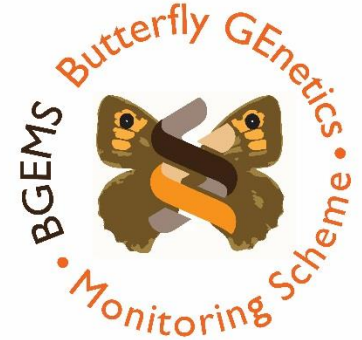
AIMS:

1. **Aichi Target 13-** An indicator for genetic diversity of wild populations

2. Understanding patterns of genetic variability at geographic range edges

3. Understanding how genetic variability mediates resilience to climate events

4. Additional analyses on spatial and temporal patterns in butterfly ectoparasites (e.g. mites) and commensals (i.e. butterfly microbiome).

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