Promoting resilience or accommodating change?

Aims for butterfly population management under a changing climate

Tom Oliver
Centre for Ecology and Hydrology
toliver@ceh.ac.uk

IUCN

UNEP

NATURAL ENGLAND

WWF

The Nature Conservancy
Protecting nature. Preserving life.

WILDLIFE CONSERVATION SOCIETY

NATIONAL WILDLIFE FEDERATION

Convention on Biological Diversity

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP

ipBes

How can we measure 'resilience'?

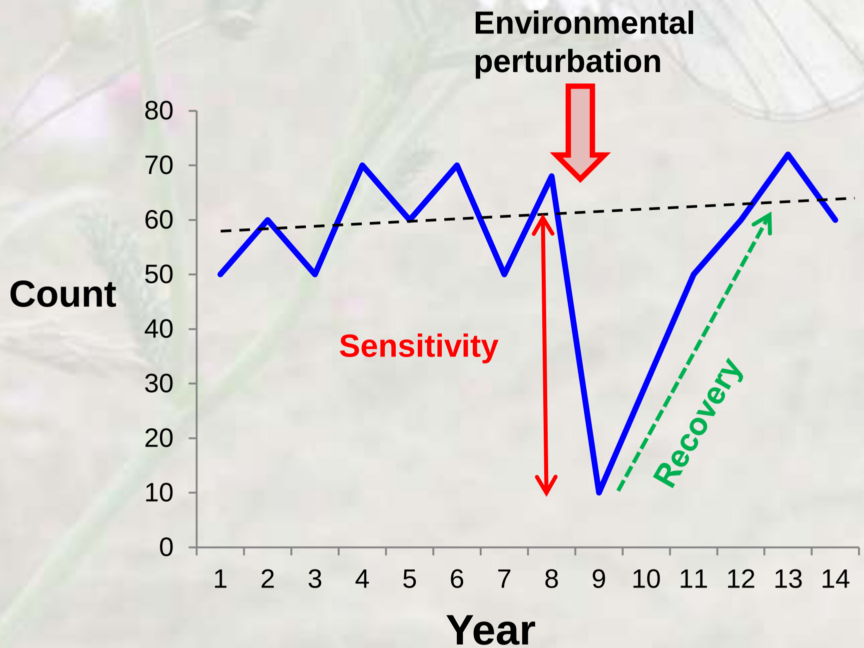
Resilience is…

….. *the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning* (Holling, 1973;, IPCC 2007)

…..*the ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change* (Pimm, 1984)

Population resilience

The ability of a population to withstand and recover from environmental perturbations



Sensitivity -

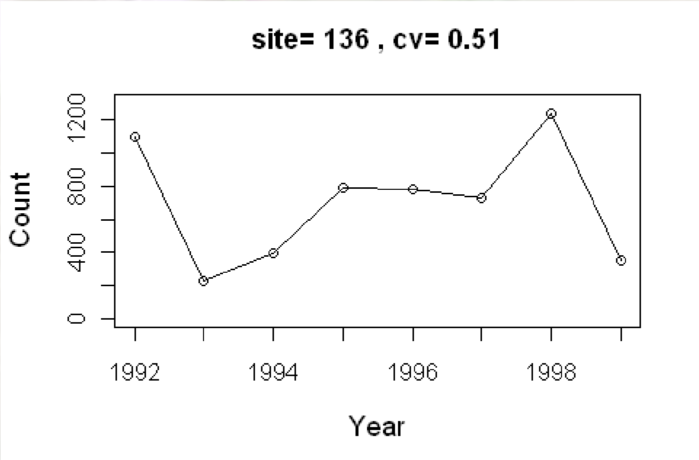
Recovery +

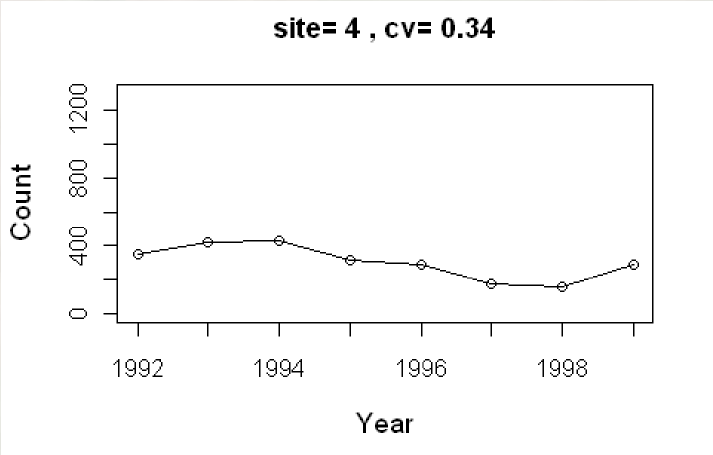
Stability of time series

Population stability

- Can be measured using coefficient of variation (CV) or standard deviation of log time series (SD)
- Theory and experiment show that stability 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.*)
- We may be able to manipulate landscape structure in order to improve population resilience to environmental perturbations

i.e. improve *adaptive capacity* (cf. IPCC 2007)

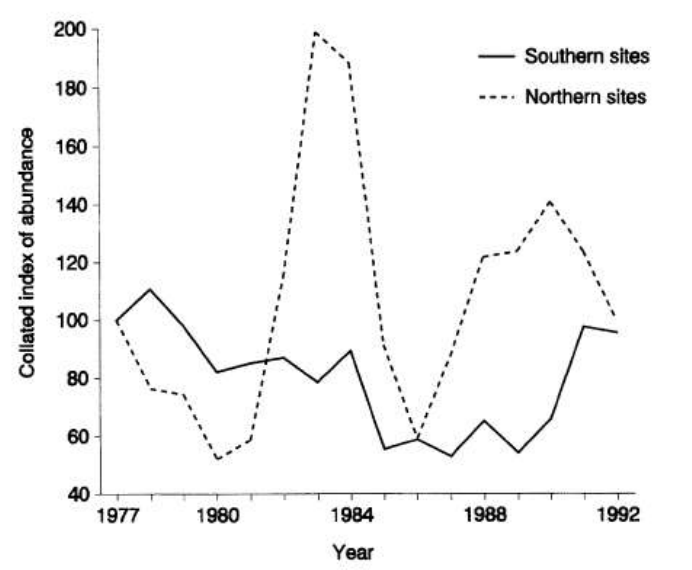




Geographical and temporal patterns in population stability

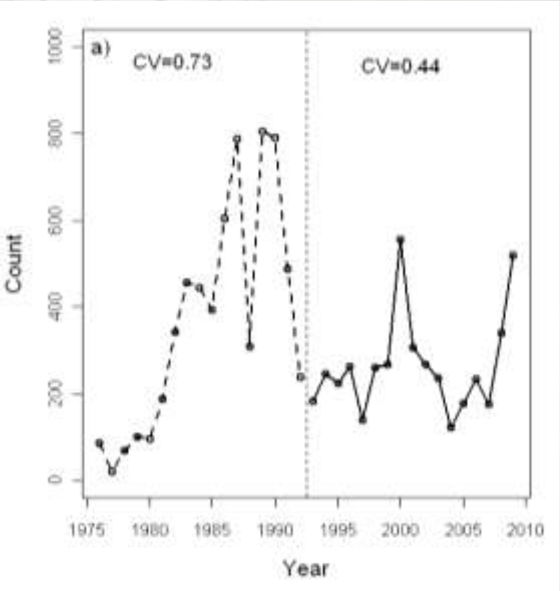
- Animal populations are thought to be less stable towards the edges of species ranges (Hansson & Hentonnen, 1985; Gaston, 2003)
- For example, butterflies populations showed increased fluctuations and synchrony at range edges (Thomas, Moss & Pollard, 1994; Powney et al. 2010)
- Although these have dampened in recent decades (Oliver et al., *GCB,* in press)

SPATIAL PATTERNS



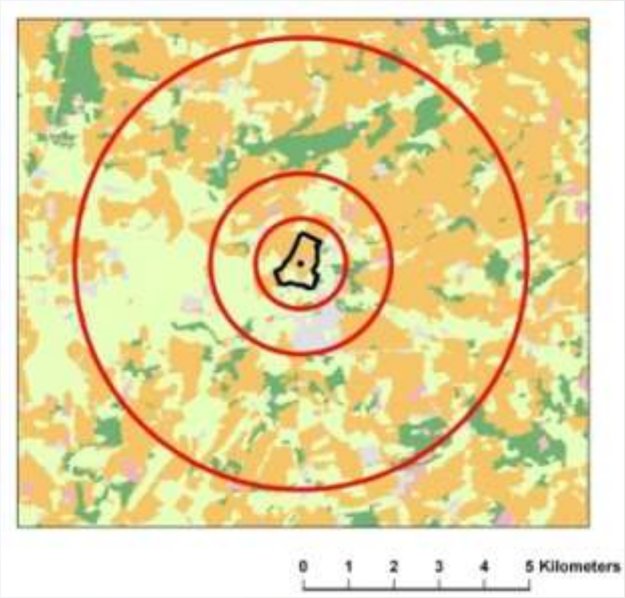
(Thomas, Moss & Pollard, *Ecography*, 1994)

TEMPORAL PATTERNS



(Oliver et al., *GCB*, 2012, online early)

Population stability and landscape heterogeneity



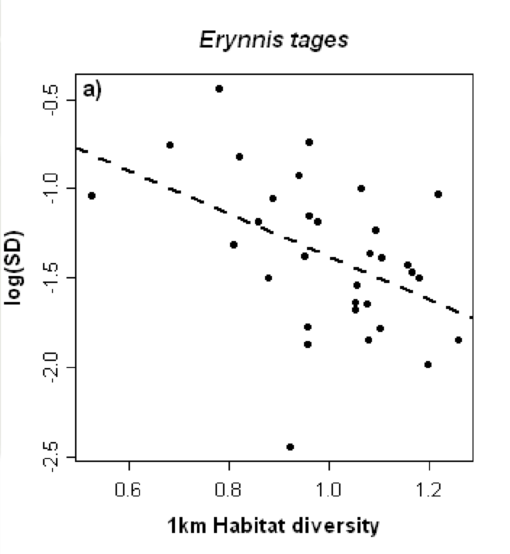
METHODS

- Habitat and topographic diversity were characterised at 1km, 2km and 5km radii around 166 UKBMS monitoring sites.
- The population variability over ~11 years was calculated at each site for 35 species.

RESULTS

Many species show lower variability in landscapes with higher habitat or topographic diversity.

Example species:



(Oliver et al., *Ecology Letters*, 2010, **13**, 473-484)

How can we measure ‘resilience’?

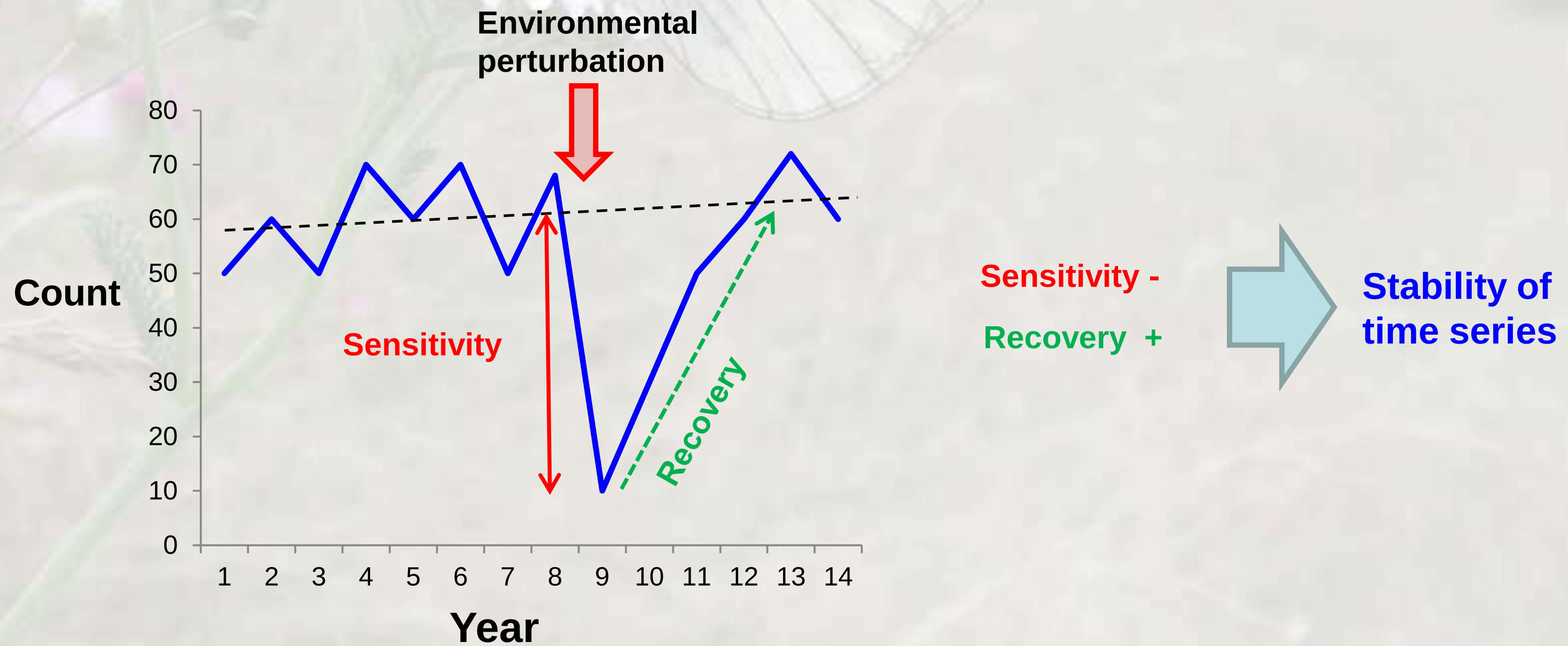
Resilience is…

….. *the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning* (Holling, 1973;, IPCC 2007)

…..*the ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change* (Pimm, 1984)

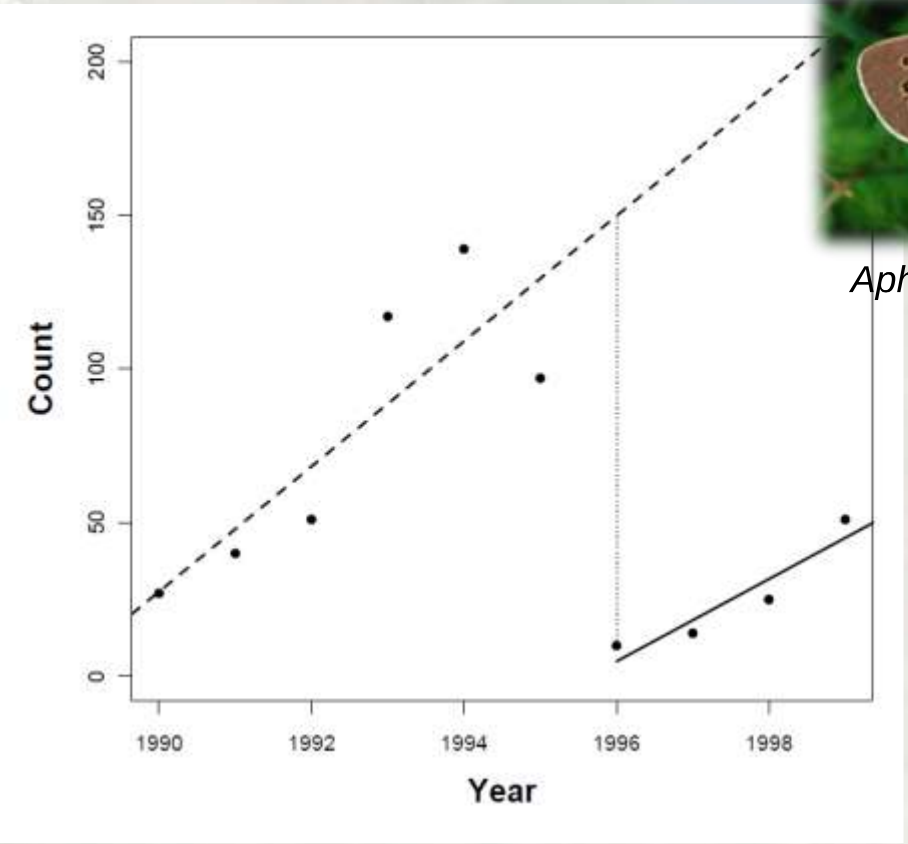
Population resilience

The ability of a population to withstand and recover from environmental perturbations



Sensitivity to- and recovery from- extreme events

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



Aphantopus hyperantus

Sensitivity to- and recovery from- extreme events

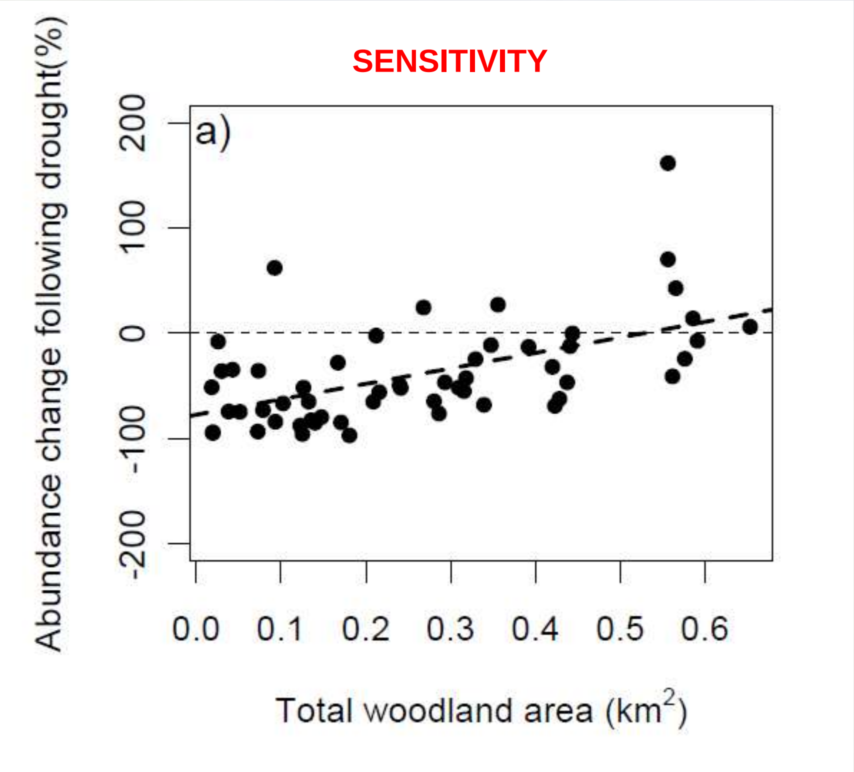
RESULTS

- Sensitivity to drought greater with lower woodland area and increased fragmentation (in terms of number of patches and the 'edginess' of each woodland patch)

- Woodland area effect strongest at 1km scale.

- Woodland configuration effect strongest at 2km scale.

Aphantopus hyperantus



Oliver *et al.* (subm.)

Sensitivity to- and recovery from- extreme events

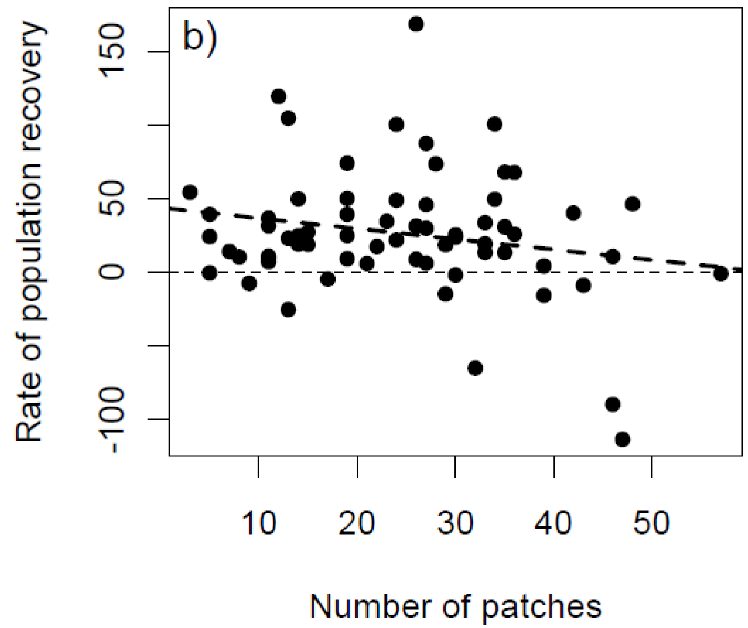
RESULTS

• Recovery from drought slower with increased woodland fragmentation (in terms of number of patches and the isolation of each woodland patch)

• Both effects strongest at 2km scale.

Aphantopus hyperantus

RECOVERY



Oliver *et al.* (subm.)

Do we really want 'resilient' communities?

Resilience is…

….. *the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning* (Holling, 1973;, IPCC 2007)

…..*the ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change* (Pimm, 1984)

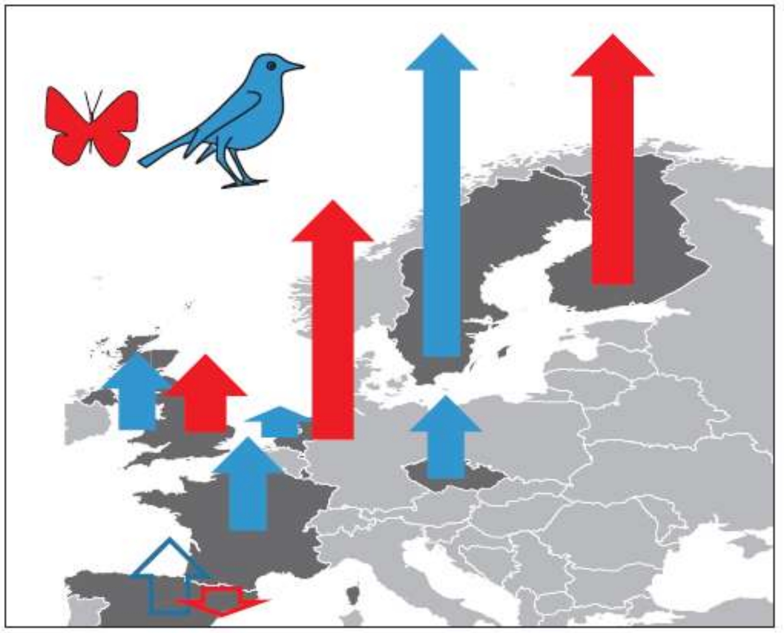
Do we really want ‘resilient’ communities?

Resilience is…

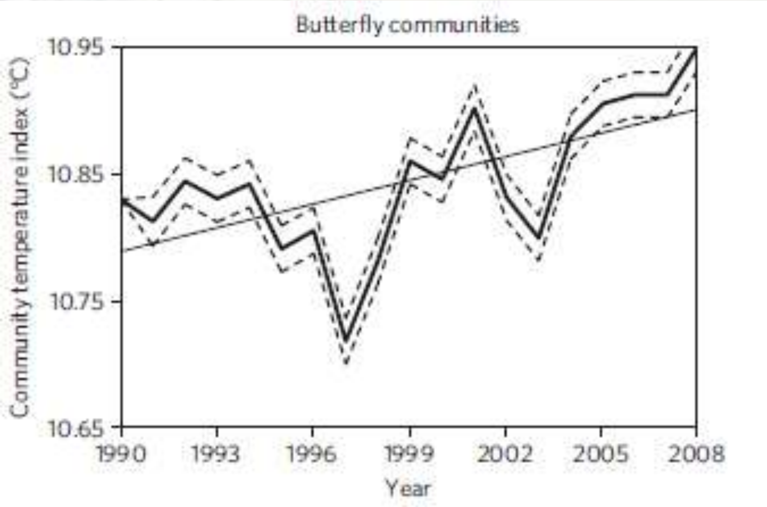
….. *the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning* (Holling, 1973;, IPCC 2007)

…..*the ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change* (Pimm, 1984)

But ecological communities are dynamic in response to climate change!



E.g. The balance of warm- versus cold-associated species increases over time



Devictor et al. (2012) *Nature climate change*; online early

Do we really want ‘resilient’ communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

•Populations ☑

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

•Populations (Trailing edge populations where costs are high and probability of success is low)

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

- Populations ✓ (X Trailing edge populations where costs are high and probability of success is low)
- Community structure X

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

- Populations ✓ (x Trailing edge populations where costs are high and probability of success is low)
- Community structure X
- Ecosystem functions (and services) ✓

e.g. Supporting services, cultural value, pollination

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

- Populations ✓ (X Trailing edge populations where costs are high and probability of success is low)
- Community structure X
- Ecosystem functions (and services) ✓ (X Where services trade-off and conscious selections are made)

e.g. Supporting services, cultural value, pollination

Do we really want 'resilient' communities...?

...or do we want to accommodate change? (Morecroft et al., *J. Appl. Ecol*, in press)

Resilience of.......

- Populations ✓ (x Trailing edge populations where costs are high and probability of success is low)
- Community structure X
- Ecosystem functions (and services) ✓ (x Where services trade-off and conscious selections are made)

e.g. Supporting services, cultural value, pollination

Sensitivity, recovery and stability as indicators

Acknowledgements

UKBMS Volunteers

David Roy (CEH), Jeremy Thomas (Oxford University/ CEH),
Chris Thomas, Jane Hill (York University)
Tom Brereton (Butterfly Conservation)




Natural England Report:
Testing climate change adaptation policy

NATURAL ENGLAND

http://www.naturalengland.org.uk/publications/publications/

toliver@ceh.ac.uk

~ 50 butterfly species & 100 birds species

Providing an evidence base for climate change adaptation principles

(Hopkins *et al.* 2007, Mitchell *et al.* 2007, Smithers *et al.* 2008, Heller and Zavaleta 2009, *Biol. Cons.)*

e.g. *Improve site heterogeneity and landscape connectivity to promote resilience*

Population stability of edge-of-range populations

Methods:

- UKBMS records split into two 17 year periods (1976-92 & 1993-2009).
- Use sites with > 7 consecutive years AND mean index > 9 in EACH separate period. Use species with > 6 sites fulfilling above criteria.
- Calculate CV and SD (omitting zeroes) of time series in each period.

Statistical analysis

- Relate population variability (e.g. CV) to site latitude and recording period.
- Account for biases caused by time series duration (Pimm and Redfearn, 1988), mean abundance (Taylor, 1961), long term abundance trends (Lepš,. (1993) .
- Multispecies and single species analysis (MCMCglmm).

$$\text{log(CV)} \sim \underbrace{\text{site.north*period}}_{\text{Explanatory variables of interest}}+\underbrace{\text{no.years+log(mean.ab)+ab.lin.trend}}_{\text{Control variables}}+\underbrace{(1|s)+(1|i)}_{\text{Random effects}}$$

Population stability of edge-of-range populations

Results: *(19 'southern' species analysed)*

1. No evidence of an interaction between position in range and change in variability.

Multispecies model

Model	Variable	Coefficient	Lower 95% interval	Upper 95% interval	
a	Site northing: recording period	0.0000	-0.0003	0.0003	
b	Site northing	0.0003	0.0001	0.0005	**
b	Recording period	-0.0717	-0.0386	-0.1002	***
b	Duration recorded	0.0259	0.0192	0.0323	***
b	log(mean abundance)	-0.0617	-0.0792	-0.0430	***
b	Log-linear abundance trend	1.9631	1.7496	2.1819	***

(Oliver et al., *GCB*, in press)

Population stability of edge-of-range populations

Results: *(19 'southern' species analysed)*

1. No evidence of an interaction between position in range and change in variability.
2. Populations show reduced variability in later recording period (93-09).

Multispecies model

Model	Variable	Coefficient	Lower 95% interval	Upper 95% interval	
a	Site northing: recording period	0.0000	-0.0003	0.0003	
b	Site northing	0.0003	0.0001	0.0005	**
b	Recording period	-0.0717	-0.0386	-0.1002	***
b	Duration recorded	0.0259	0.0192	0.0323	***
b	log(mean abundance)	-0.0617	-0.0792	-0.0430	***
b	Log-linear abundance trend	1.9631	1.7496	2.1819	***

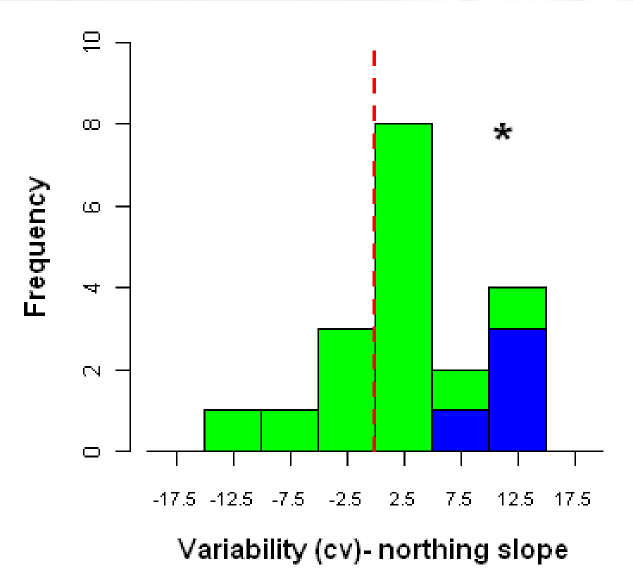
(Oliver et al., *GCB*, in press)

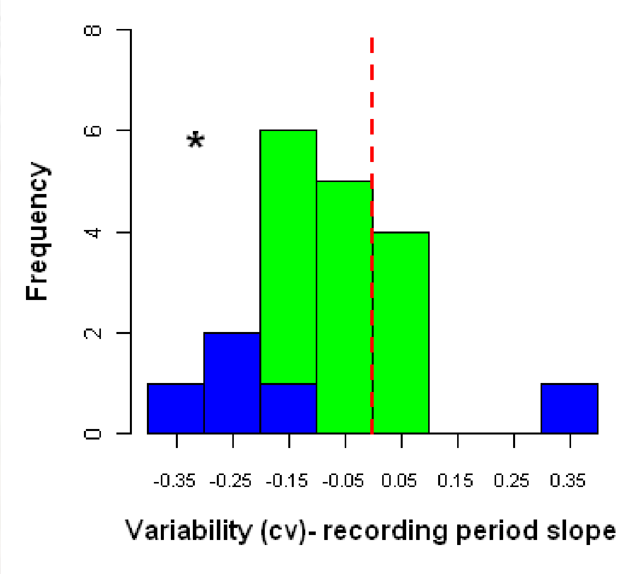
Population stability of edge-of-range populations

Results: *(19 'southern' species analysed)*

3. Results consistent with different measures of variability (CV, SD), inclusion of mean abundance in models, and with species modelled individually.

Single species models





Increased variability in north

Increased variability in later recording period

(Oliver et al., *GCB*, in press)

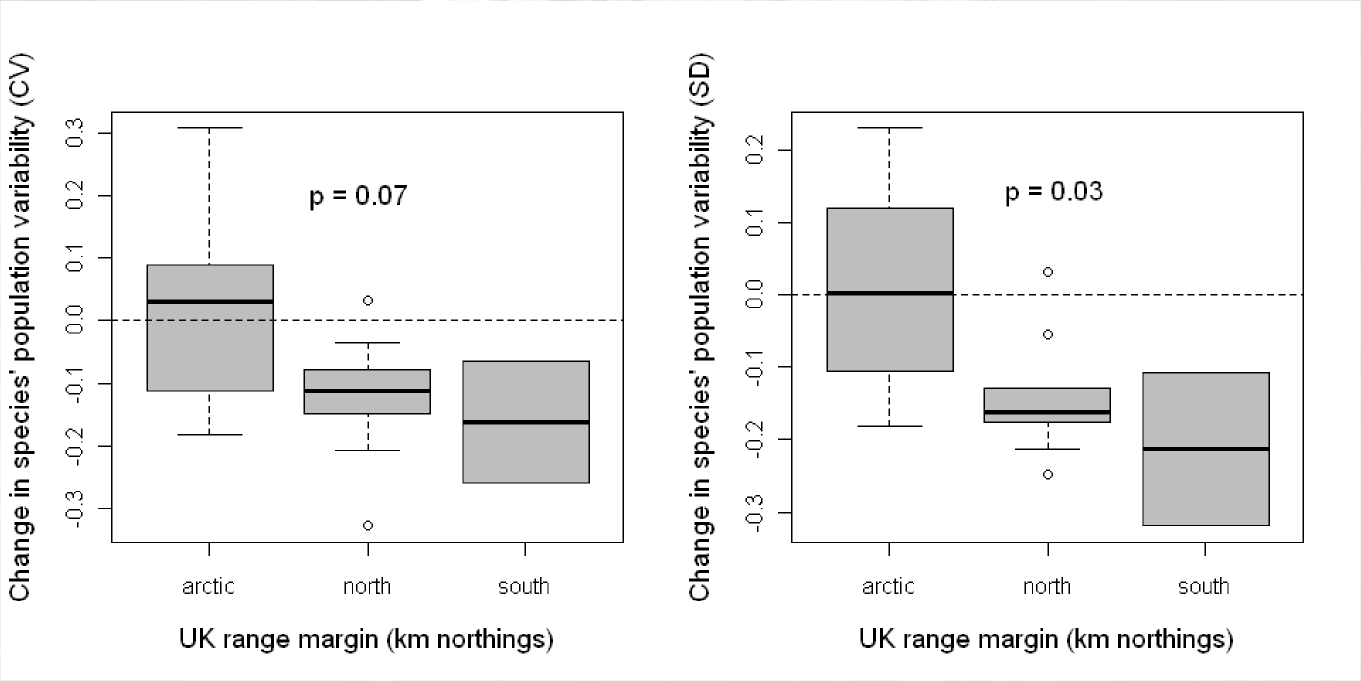
Best wishes,
Tom

Population stability of edge-of-range populations

Methods:

Classify British species by the northern limit of their European range margin- within Britain, between Britain and Arctic circle, north of Arctic circle.

Results: Southerly distributed species show greatest dampening in population dynamics between the two recording periods



(Oliver et al., *GCB*, in press)

Landscape heterogeneity and population stability

Specific case studies:

1. Fine-scale grassland heterogeneity reduces temporal variability and extinction risk of *Metrioptera bicolor* crickets (Kindvall, 1996, *Ecology*)
2. Diversity of habitat types at landscape scale increases persistence of *Rana temporaria* frogs in drought years (Piha, 2007, *Glob. Ch. Biol.*)

Is this a general phenomenon?

– Multiple species

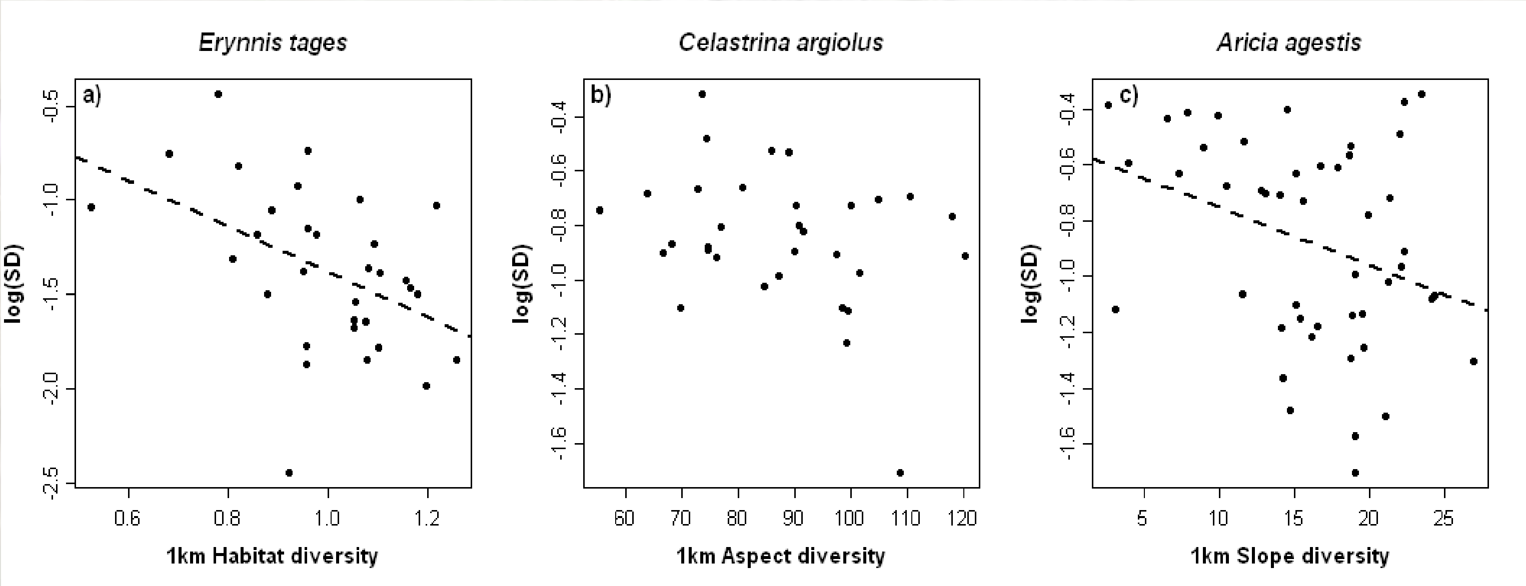
- Account for biases in measures of variability (**Zero counts**; *McArdle, Gaston and Lawton, 1990, J. Anim. Ecol),* **Time-series duration**; Pimm and Redfearn, 1988, *Nature)*, **Mean abundance**; Taylor, 1961, *Nature*), **Long term population trends** (Lepš, 1993, *Oikos)*; **Position in range** (Thomas, Moss & Pollard, 1994, *Ecography*)

- Also, which at which spatial scale is it best to relate population variability to landscape structure?

Results

- Many species show lower variability in landscapes with higher habitat or topographic diversity
- Three example species:



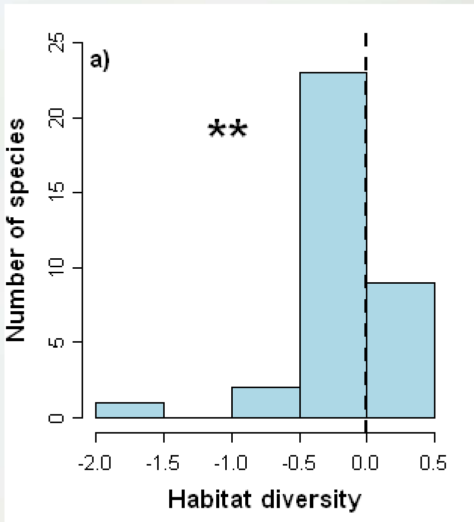


Oliver *et al.* (2010) *Ecol. Lett.* 13: 473-484

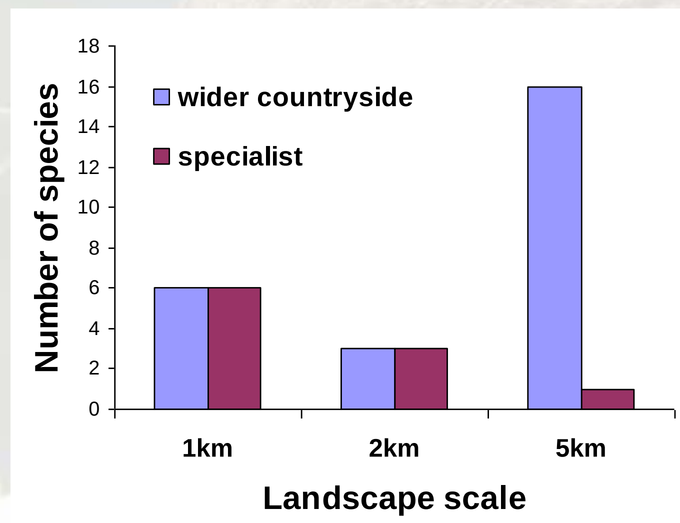
RESULTS #2

Across all 35 species, there were significant relationships between habitat diversity and topographic aspect diversity on population variability.

E.g. histograms of slope coefficients:



The most appropriate spatial scale to characterise landscape diversity differed between specialist and wider-countryside species



Oliver, T. H., D. B. Roy, J. K. Hill, T. Brereton, and C. D. Thomas. 2010. Heterogeneous landscapes promote population stability. *Ecology Letters* 13, 473-484.

Mechanisms?

1. Different population dynamics between habitat types/ topographic formations due to differences in microclimate, resource availability, land management, natural enemy intensity etc.

➢ Leads to asynchronous dynamics, yet whole population across habitat types has a more stable average (den Boer, 1981, *Oecologia*; Thomas, 1991 *Oecologia*)

2. Dispersal between habitat types dampens temporal variability

e.g.

SHORT TERM

– short term behavioural thermoregulation or resource acquisition (Ashton *et al.* 2009, *Ecol. Ent.;* Dennis & Shreeve, 2003 *Oikos*)

– different microclimates for different generations (Roy and Thomas, 2003, *Oecologia*)

– different microsites between years depending on weather (Weiss et al, 1988, *Ecology*; Davies *et al*., 2006, *J. Anim. Ecol.*)

LONGER TERM

Implications for conservation

1. Heterogeneity of the wider landscape is important for maintaining stable populations of species.
2. Improving landscape heterogeneity should increase the resilience of populations to environmental change.
3. Species responses may depend on functional traits.

Implications for conservation

1. Heterogeneity of the wider landscape is important for maintaining stable populations of species.
2. Improving landscape heterogeneity should increase the resilience of populations to environmental change.
3. Species responses may depend on functional traits.

Implications for conservation

1. Heterogeneity of the wider landscape is important for maintaining stable populations of species.
2. Improving landscape heterogeneity should increase the resilience of populations to environmental change.
3. Species responses may depend on functional traits.

Sensitivity to- and recovery from- extreme events

METHODS

1. Calculate magnitude of decline in 1996 (sensitivity) and recovery rate (abundance slope 1996-9)

2. Include control variables in models:

Sensitivity analysis: site APET in 1995, expected abundance in 1996

Recovery analysis: observed abundance 1996, magnitude of decline in 1996

3. Relate sensitivity and recovery to woodland area and configuration (number of patches, 'edginess' and isolation) at 1,2, 5 & 10km radius.