SHIFTING SEASONS, CLIMATE CHANGE & ECOSYSTEM CONSEQUENCES

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Phenology & the global “fingerprint”

- The study of the timing of natural events:
  - egg laying
  - flowering

- Many spring events have been getting earlier.

- This has been linked to climate change (IPCC assessments).
Phenology and synchrony

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Thackeray et al. (2010), Global Change Biology, 16, 3304-3313.

Climate and synchrony

**Fig. 1. Climate sensitivity of phenology for two hypothetical species (dotted and dashed lines).**

- **A** – one species is affected by climate and the other is not (due to alternative drivers),
- **B** – both are affected by climate but at different rates or,
- **C** – both are affected at a similar rate but each is affected by climate at a different time of year (and rates of climate change differ seasonally).

**Strength of climate response**

- **Species 1**
- **Species 2**

- **Only one species is climate-sensitive**
- **Both species are climate-sensitive, but to different extents**
- **Both species are climate-sensitive, but at different times of year**
Climate and synchrony

Climate and synchrony

≈6-7 days earlier °C⁻¹

≈8 days earlier °C⁻¹

≈4 days earlier °C⁻¹

Thackeray et al. (2013) Global Change Biology, 19: 3568-3580
Climate sensitivity of phenology

- Large-scale climate-phenology analyses: (average) phenological change is consistent with climate warming.

- Does the climate sensitivity of phenology differ with respect to species traits?

- Could this drive widespread de-synchronisation?

Key questions

Within this “bigger picture”:

• Which species show the greatest climate-sensitivity with respect to their seasonal timing?
• Do species at different levels in the “food chain” have fundamentally different responses?
• Which species traits are associated with strong-climate sensitivity?
The “shifting seasons” project

• Statistically model thousands UK phenology series as a function of gridded temperature data.
• Collate the quantitative features of these relationships.
• Group species according to their climate responsiveness, based upon these features.
The project

• NERC funded. Runs September 2012-February 2015.
• We will address 4 key questions:
  1. Does the strength/nature of link between climate and phenology differ with species traits/trophic level? (Lead: CEH)
  2. To what extent has human-induced climate change impacted upon phenology? (Lead: CEH, Met Office)
  3. In what regions/habitats is de-synchronisation most severe? (Lead: Rothamsted Research)
  4. Can spatial variations in predator reproductive success be linked to spatial variations in de-synchronisation? (Lead: British Trust for Ornithology)
A multi-species study for the UK

- Marine and freshwater phyto-/zooplankton – growth period
- Freshwater fish, amphibians – spawning
- Marine and terrestrial birds – egg laying, migration
- Aphids, moths, butterflies – flight
- Mammals – births
- Terrestrial plants – leafing, flowering, fruiting

>10,000 time series
UK temperature/precipitation data

- Station network is irregularly spaced and changes with time
- Observations interpolated on a regular (5km) grid, using inverse distance weighting. Topography is taken into account.
Analysis approach, step 1

- Phenology related to Met Office gridded temperature/precipitation data.
- Time window of climate influence identified.
Analysis approach, step 1

• Analysis allows 2 time windows each for temperature and precipitation, in which effects might be opposing.

• When do rising temperatures (precipitation) most strongly **advance** seasonal timing?

• When do rising temperatures (precipitation) most strongly **delay** seasonal timing?
Analysis approach, step 2

• Define climate response groups

- How much variation in phenology is explained by temperature?
- How rapidly does phenology change with temperature (days per degree C)?
- In what seasonal window is temperature most influential?
Multi-species output

- 10,003 series, 812 taxa

- Example plots:
  - Variation in the ability of climate to “explain” changes in seasonal timing
  - Seasonal windows within which warming advances seasonal events

~36%
Cluster analysis

Parameters:
- slopes of temperature effects
- standard errors of slopes
- P values of effects
- % deviance explained
- start and end of time windows for temperature effects
- AIC comparison with linear temporal trend

10,003 series, 812 taxa

~36%
Interpretation: exploratory approach

- What kind of climate-phenology relationship typifies each group?
- Which taxa (with which traits) are found in each group?
“Global” models for each cluster

Mixed-effects (random slopes) model:

\[ \text{DOY}_{y,s} \sim \beta \text{Temp}_{y,s} + \beta \text{Precip}_{y,s} + b_s \text{Temp}_{y,s} + b_s \text{Precip}_{y,s} + \epsilon_{y,s} \]

Where:
DOY is the day-of-year of an event, in year \( y \), for species \( s \)

Slope of the relationship between climate and phenology varies among species

Example: Cumbrian Lakes plankton, 47 taxa
Interpretation: hypothesis testing approach

- Are clusters defined by trophic level, and other traits, significantly different?

- Are broad traits correlated with climate sensitivity?
Habitat: where you live matters

- Woodlands may buffer temperature change.
- Grasslands may be exposed to more dramatic change.
Habitat/spatial analyses

- Important to note that ‘predator-prey de-synchronisation’ is *generalised*.

- *Generalised* trophic links (i.e. secondary consumers eat primary consumers etc) will be used as an indication of what may be happening within different UK habitats.
Single system analyses

- Barn Swallow (*Hirundo rustica*) and aphids
- Tit species and moths
Single system analyses

- Rothamsted invertebrate datasets and BTO avian datasets.

- Spatial matching using GIS software.

- Assess impact of desynchronisation on both breeding success and abundance.
Measures of breeding success

- BTO Nest Record Scheme breeding parameters:
  - First egg date (+/- 5 days)
  - Clutch size
  - Brood size (at known age)
  - Egg stage failure rates
  - Chick stage failure rates
  - Fledgling production – number per attempt

- Breeding Bird Survey abundance – max count per annum.
Summary

• The “shifting seasons” project is a national-scale assessment of the links between phenology and climate.

• Key questions:
  ➢ How does climate sensitivity of phenology differ among species groups?
  ➢ Where is de-synchronisation likely to be most severe?
  ➢ Has de-synchronisation impacted upon the breeding success of wild populations?

Thank you for your attention!
Acknowledgements

We are funded by NERC Grant NE/J02080X/1: “Quantifying links between human influences on climate, shifting seasons and widespread ecosystem consequences”

We are indebted to our project partners, and to all who record phenology data in the UK

http://www.ceh.ac.uk/sci_programmes/shifting-seasons-uk.html