Applying Volunteer-based Butterfly Monitoring Data Toward Understanding the Responses of Butterflies to Global Climate Change

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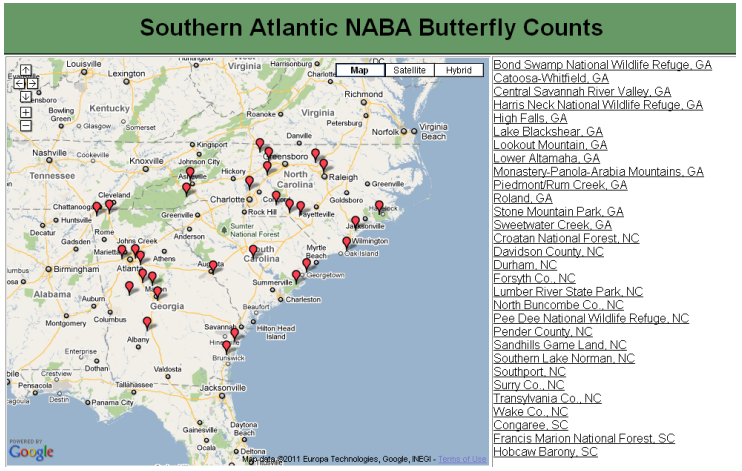
Roadmap

- Overview of volunteer-based butterfly monitoring
- The UK Butterfly Monitoring Scheme (UKBMS)
- Applying monitoring data to develop predictive models for butterfly species' responses to climate change

Volunteer-based butterfly monitoring

- Single-day counts
  - 4 July counts [June-July] (and potentially more times per year [spring/fall], depending on the site)
  - e.g., North American Butterfly Association (NABA)

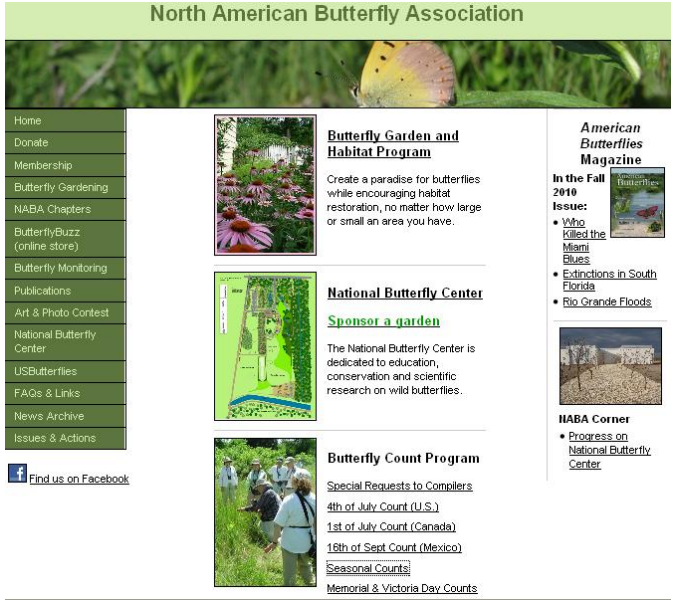


- Recurring counts
  - Often involve once-per-week counts for the duration of butterfly activity
  - e.g., UK Butterfly Monitoring Scheme (UKBMS)

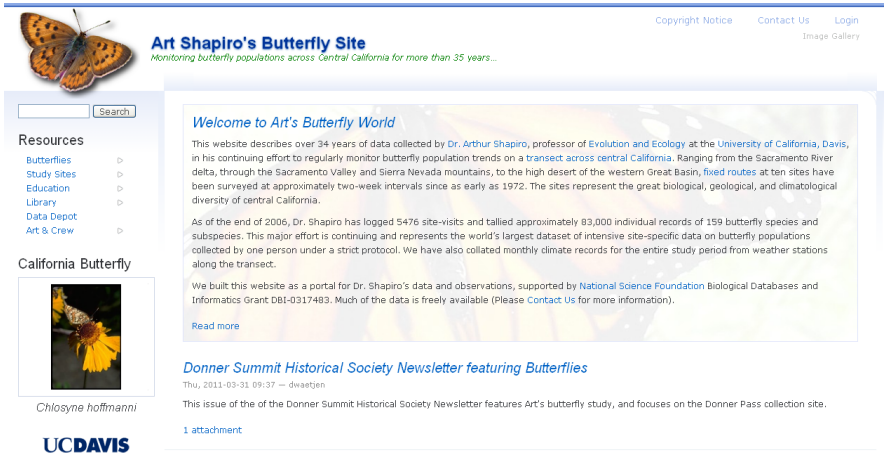
Volunteer-based butterfly monitoring

- Areas
  - NABA: participants select a count area with a 15-mile diameter and conduct a one-day census of all butterflies sighted within that circle

- Transects
  - UKBMS: participants walk transects (~1-4 km length x 5 m width) once-per-week starting 1 April through September, and census all butterflies along the transect (Pollard transects)



Mix of single-day, recurring, area, and transect butterfly monitoring in the US



Data collection and deposition

- Quality control on data
  - NABA: minimum four adult observers, and 6 party-hours per count
    - Data not conforming can still be submitted to Butterflies I've Seen (BIS)
  - UKBMS: transect walks are undertaken between 10:45am and 3:45pm and only when weather conditions are suitable for butterfly activity: dry conditions, wind speed less than Beaufort scale 5, and temperature 13°C or greater if there is at least 60% sunshine, or more than 17°C if overcast
  - Online field guide resources for identifications
  - Submission of butterfly photographs with count data for confirming identifications
- Most volunteer butterfly monitoring data are freely available from the web or upon request

Why monitor butterflies?
Butterfly phenology as an indicator of climate change

- **Phenology**: “recurring plant and animal life cycle stages, such as leafing and flowering, maturation of agricultural plants, emergence of insects, and migration of birds”

- With climate warming, phenologies of many organisms shifting
  - Empirical evidence for earlier spring events & later fall events
  - Asynchronies in timing of events as taxa have different phenological responses to warming

- Phenology identified by the Intergovernmental Panel on Climate Change (IPCC) as a key indicator of biological responses to climate change

United Kingdom Butterfly Monitoring Scheme

Home | About | Methods | Obtaining data | Using data | Links | Contact | UKBMS

HOME

- How to get involved
- Wider countryside butterfly survey
- Butterflies as indicators
- Key Findings
- News
- Reports & Publications
- Resources
- Species Lists
- Site Locations

The UK Butterfly Monitoring Scheme (UKBMS)

Welcome to the United Kingdom Butterfly Monitoring Scheme (UKBMS), a recently formed merger of the long-running Butterfly Monitoring Scheme (BMS) with Butterfly Conservation's co-ordination of 'independent' transects. The resulting UKBMS dataset is one of the most important resources for understanding changes in insect populations... [more]

The scheme has monitored changes in the abundance of butterflies throughout the United Kingdom since 1976. Over the 32 years of the scheme, recorders have made over 170,000 weekly visits to 1500 separate sites, walking over 375,000 km and counting over 12.5 million butterflies!

The UKBMS is based on a well-established and enjoyable **recording method** and has produced important insights into almost all **aspects of butterfly ecology**.

Aporia crataegi © Eddie John

Volunteer-based
71 species
1500 sites
~ 26 sampling events / yr
Sampling 1976 to present

Latest News

The **Wider Countryside Butterfly Survey** is in full swing this summer.

2009 Summary of Changes Table now available online

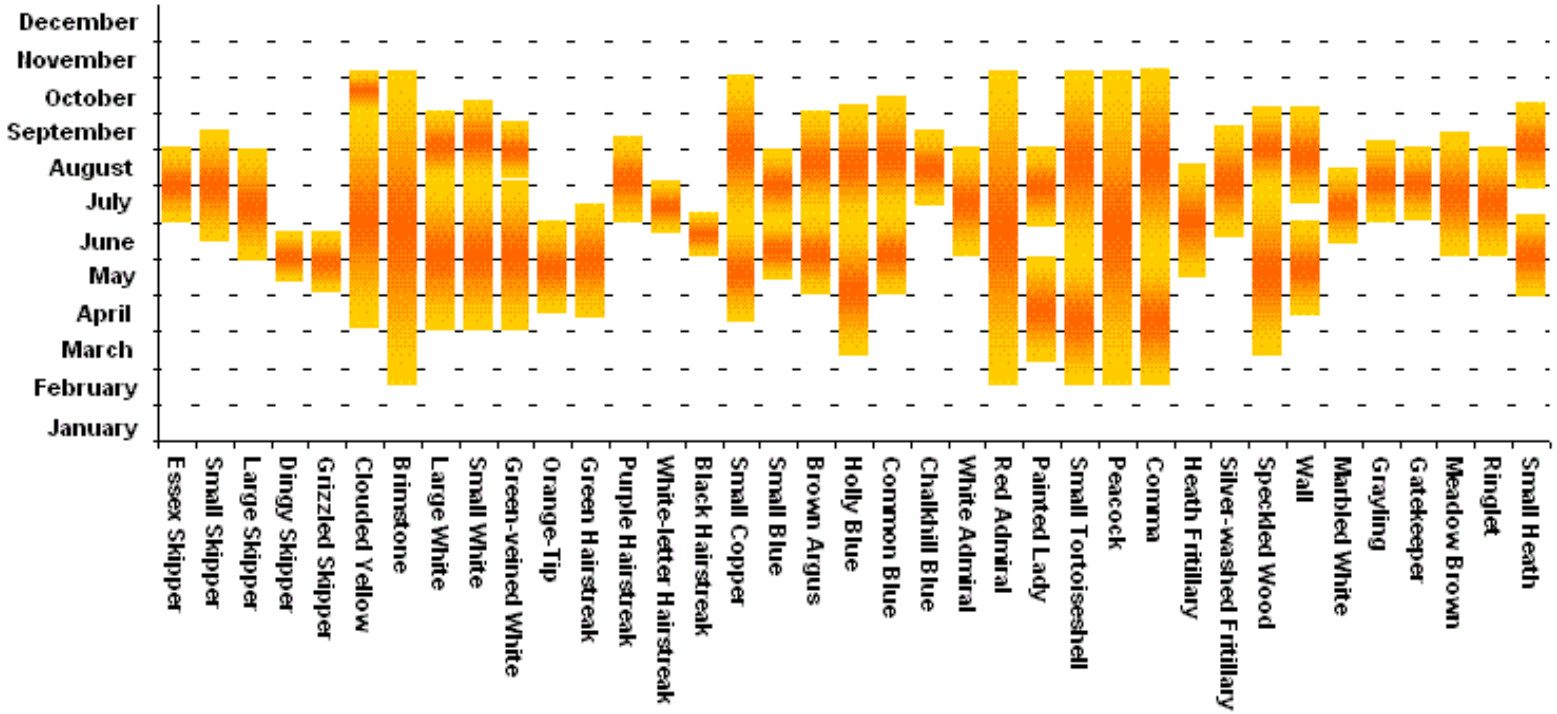
2010 National Butterfly Recorders' Meeting Full programme now online.

2008 Annual Report To download **High Res** (38.2 MB, PDF) **Low Res** (3.1 MB, PDF)

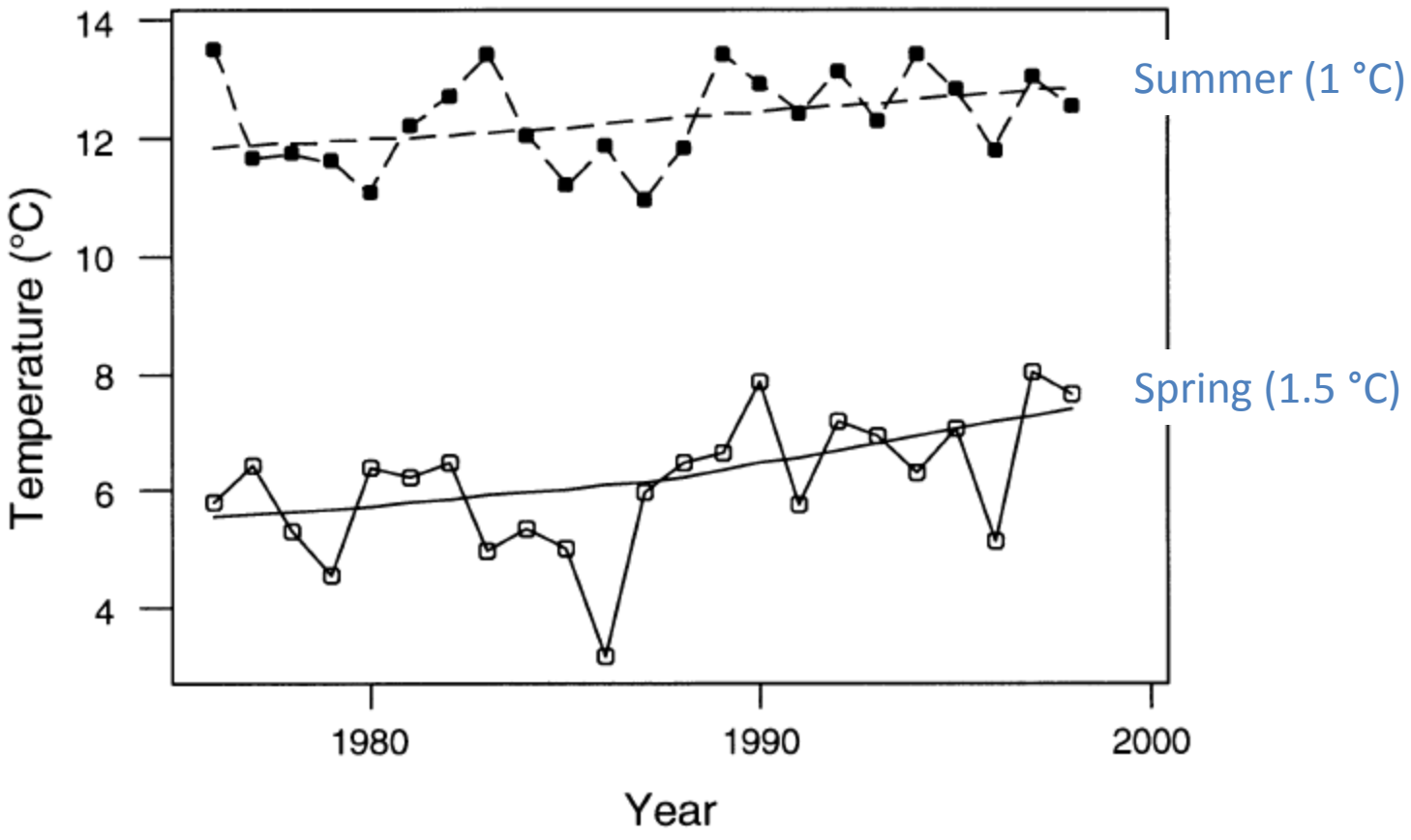
Amendment to the 2008 Annual Report

A new publication, "**The State of Butterflies in Britain and Ireland**", was launched on May 15th. This book is a follow-up to the hugely successful **Butterflies for the New Millenium atlas**, and is available to purchase from the publishers, **Nature Bureau** (price: **£14.50 inc. p&p**)

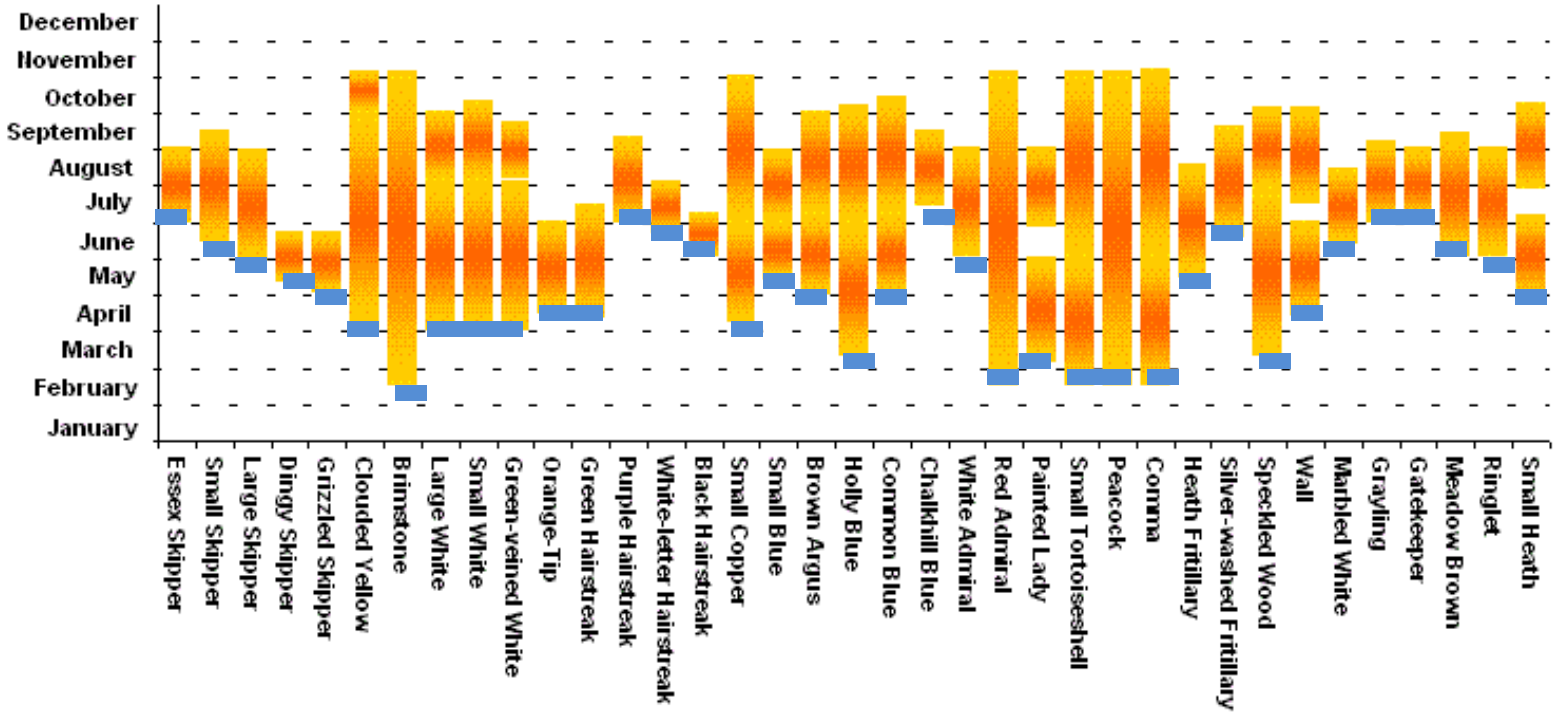
Flight phenology of UK butterflies



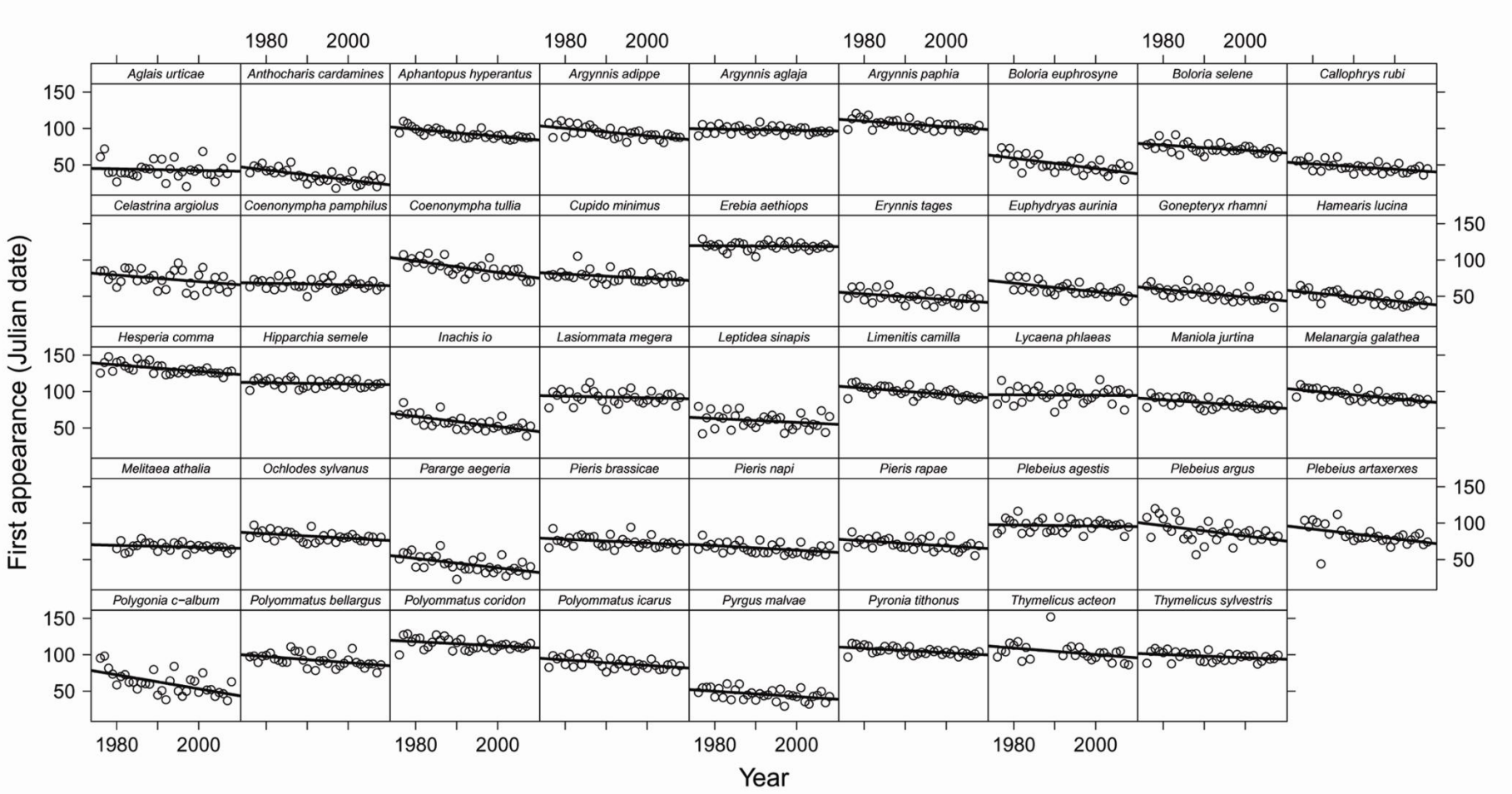
Increase in UK air temperature



Flight phenology of UK butterflies: Date of first appearance

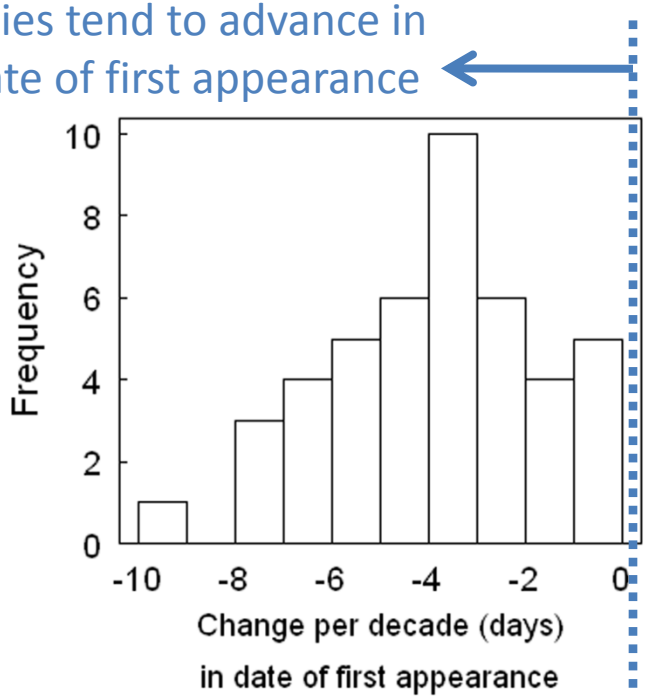


Phenology of UKBMS species (1976-2008)



Phenological change per decade

All species tend to advance in their date of first appearance

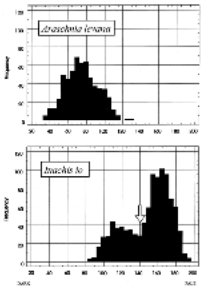


Can species' traits and shared evolutionary history explain the degree of phenological advancement?

Diet breadth

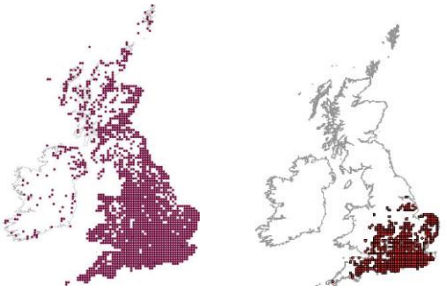
Overwintering stage

Voltinism

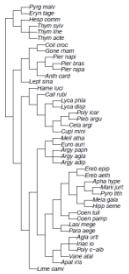


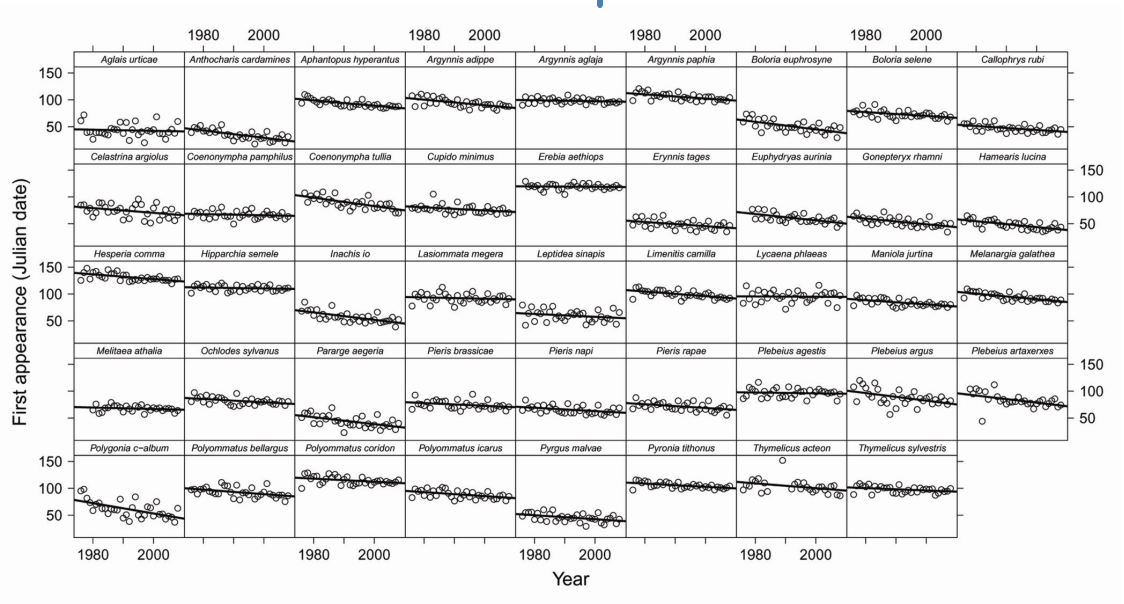
Dispersal

Range & distribution



Phylogeny





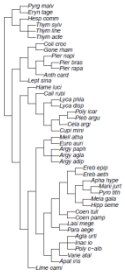
Analytical approach: phylogenetic glm

- linear model controlling for phylogenetic non-independence
- strength of the phylogenetic signal controlled by altering the parameter λ
  - λ = 0 is equivalent to a standard linear model, with all shared phylogenetic history reduced to zero
  - λ = 1 uses the original covariance matrix
  - pglm scales the covariance between data points as the product of this shared history and λ (estimated using ML)

$$\Sigma = \begin{pmatrix} \sigma_{11} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \\ \vdots & & \vdots \\ \sigma_{n1} & \cdots & \sigma_{pp} \end{pmatrix}$$

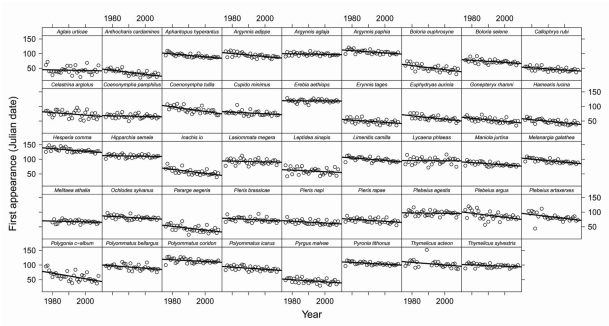
The goal: build a predictive model for butterfly phenological responses to climate warming based on species-level traits

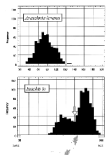
Phylogenetic autocorrelation



Overwintering stage
(egg, larva, pupa, adult)

Change in day of first appearance
(per decade)





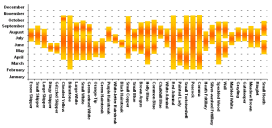
Voltinism

Dispersal ability

Number of larval host plant species

Latitudinal extent
(amount of UK mainland occupied)

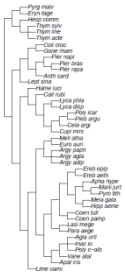
Percent national 10km grid cells occupied



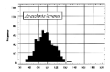
Julian day first appearance (1975)

λ ~ 0 (full model pglm); Moran's I = -0.02, p = 0.41
Virtually no phylogenetic signal in phenological advancement

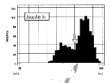
Phylogenetic autocorrelation



Overwintering stage
(egg, larva, pupa, adult)



Voltinism



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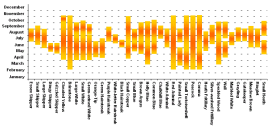
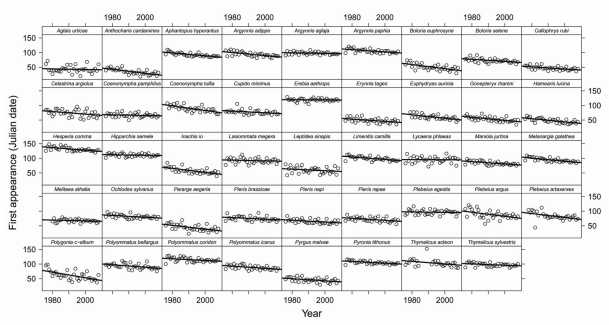


Julian day first appearance (1975)

Change in day of first appearance
(per decade)

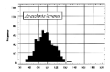


Model selection approach:

what combination of parameters best predicts the degree of phenological advancement?

(all main and two-way interactions)

Overwintering stage
(egg, larva, pupa, adult)



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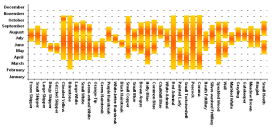

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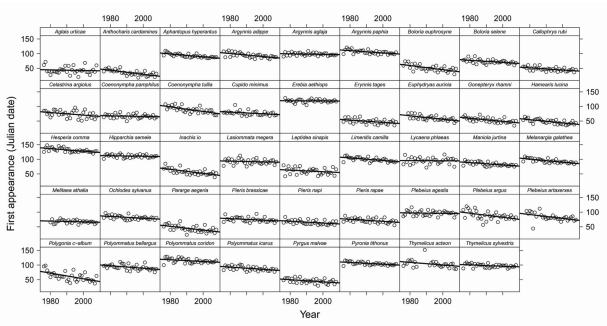


Best-fitting models (ΔAICc < 2)

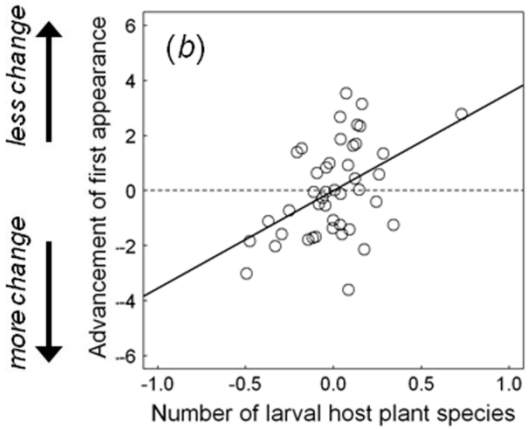
Dispersal and voltinism absent from best-fitting models

Models with strongest empirical support contain: annual day of first appearance, overwintering stage, diet breadth, and range/distribution

Model no. (*i*)	**Model wt. (w_i)**	**First app.**[b]	**Overw. Stage**	**No. Plants**	**Per. Nat.**	**Lat. Ext.**	**No. Plants* Per. Nat.**	**No. Plants* Lat. Ext.**	**Per. Nat.* Lat. Ext.**
1	0.394		●	●	●	●		●	●
2	0.250	●	●	●	●	●		●	●
3	0.144	●	●	●	●	●	●		●
4	0.111	●	●	●	●	●		●	●
5	0.101		●	●	●	●	●		●
w_{+i} [a]	1.000 (cum. w_+)	0.505	1.000	1.000	1.000	1.000	0.245	0.755	1.000

Partial regression plot

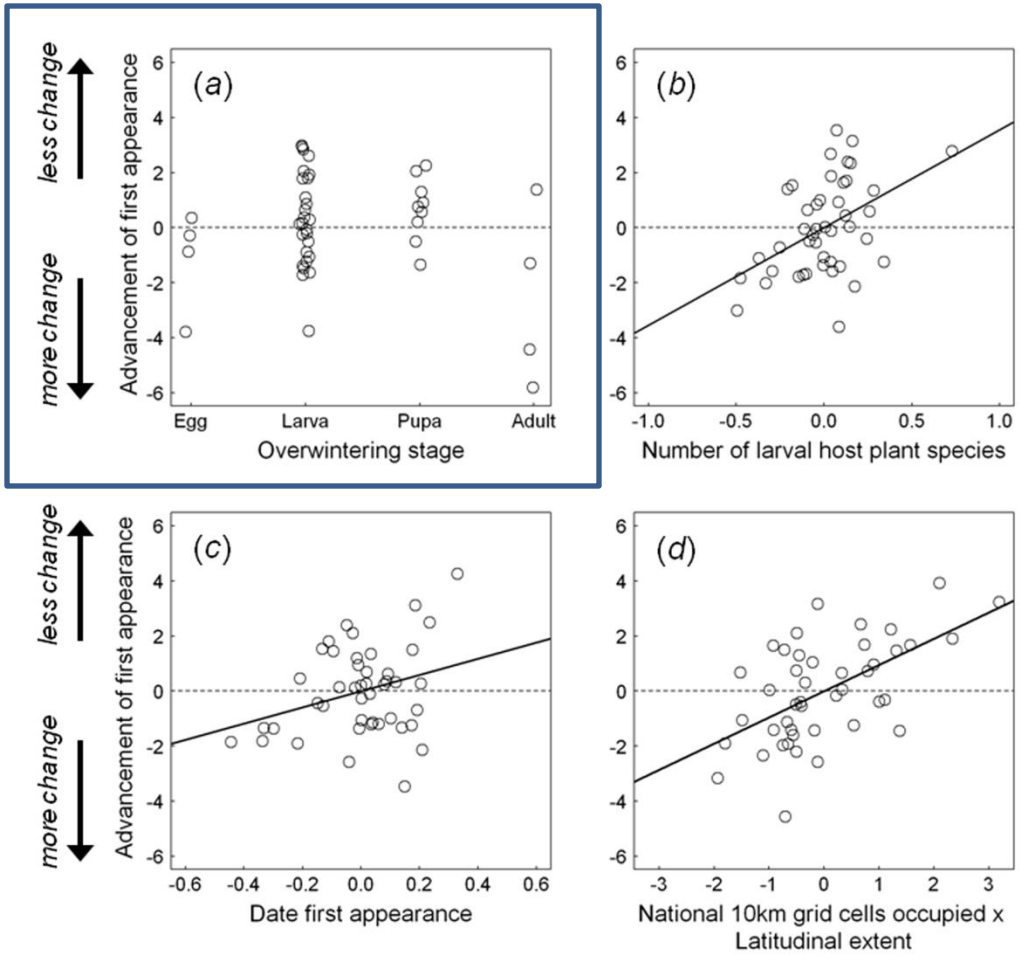
Residuals of
$y \sim x_i \ldots x_n (- x_*)$



Residuals of
$x_* \sim x_i \ldots x_n$

‘Significant’ predictors ($p < 0.05$, full model of all terms from best-fitting models; type III SS)

Species that overwinter as adults advance more than other stages



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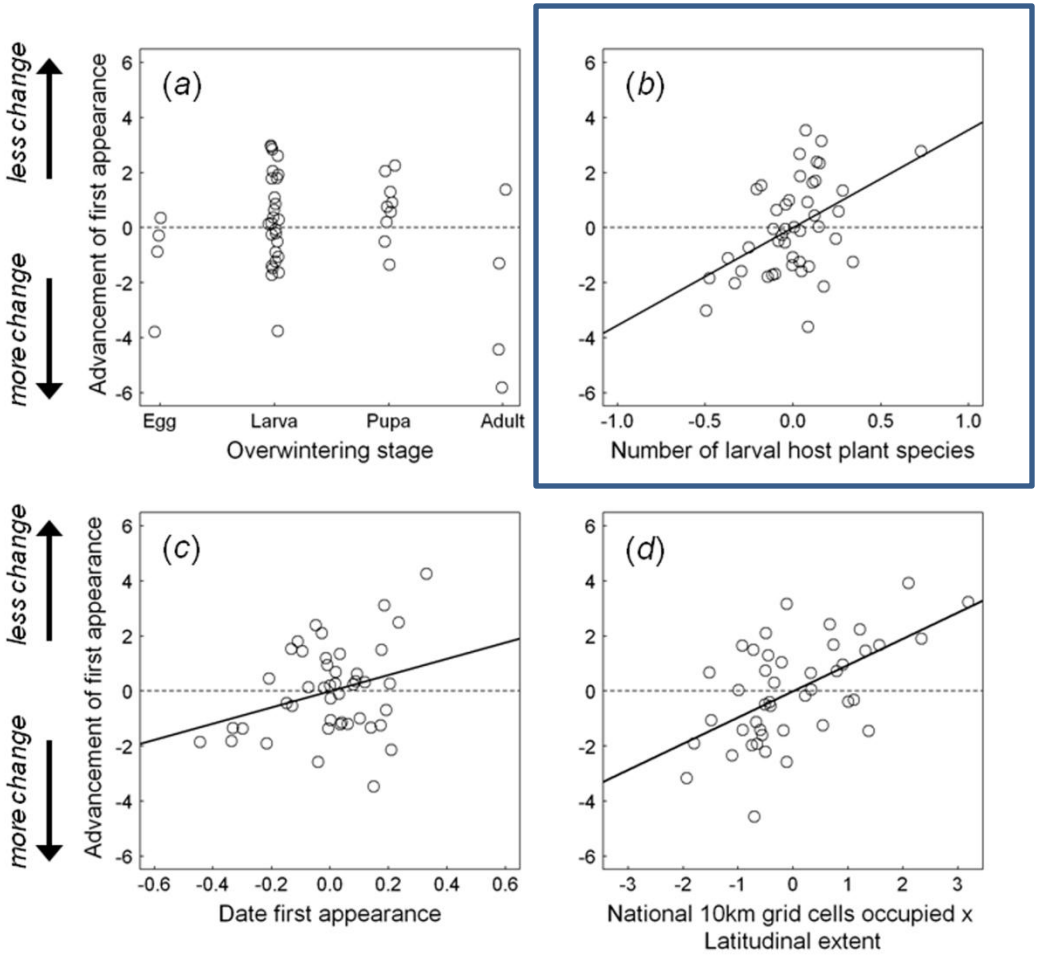
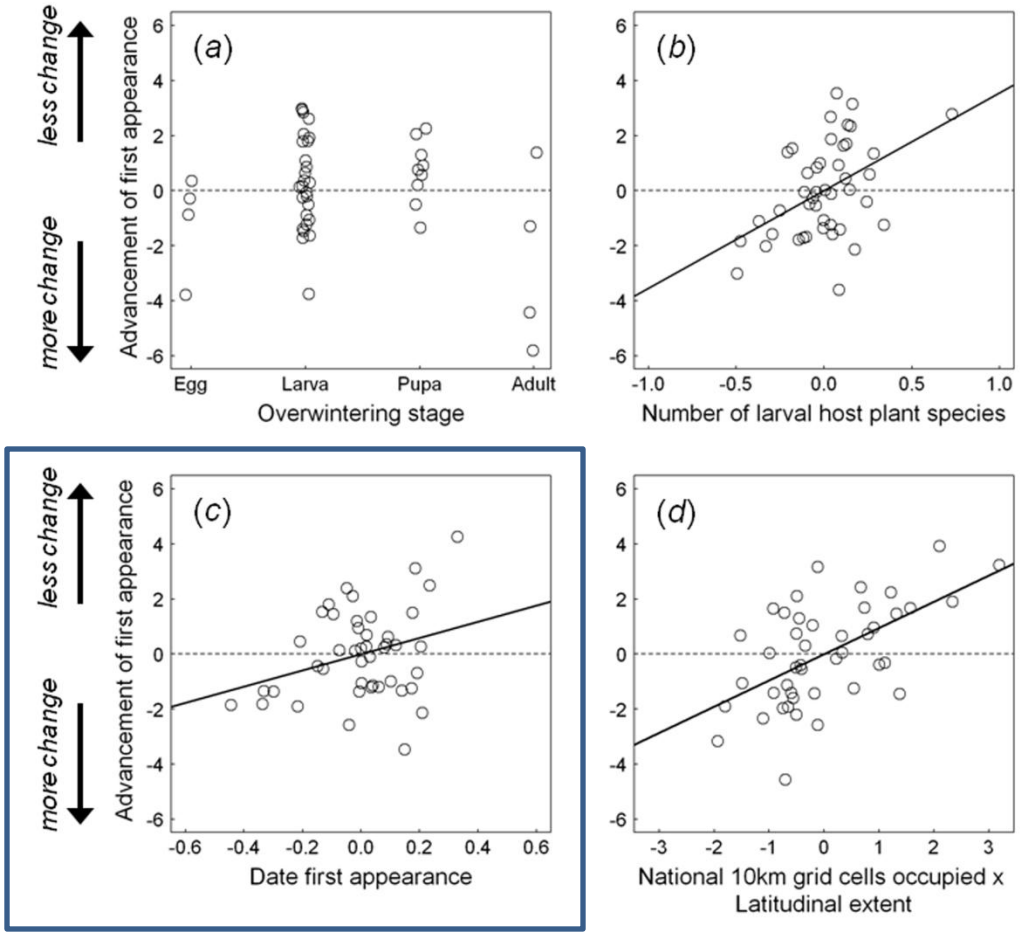


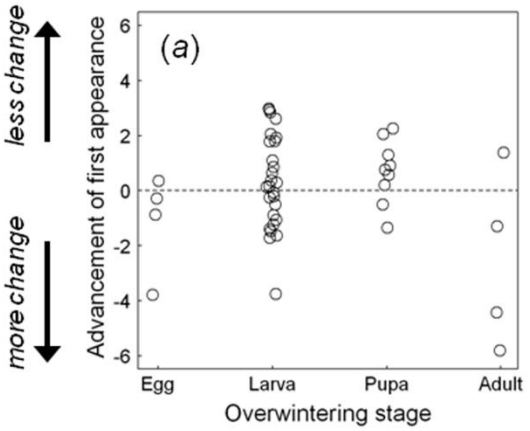
Species with narrower diet breadths advance more

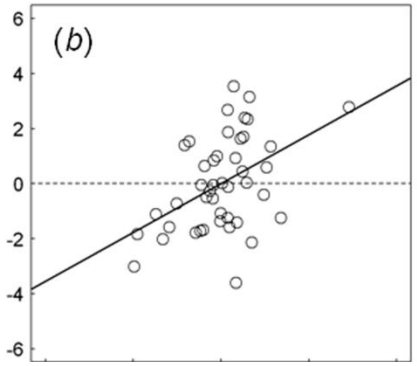
‘Significant’ predictors ($p < 0.05$, full model of all terms from best-fitting models; type III SS)

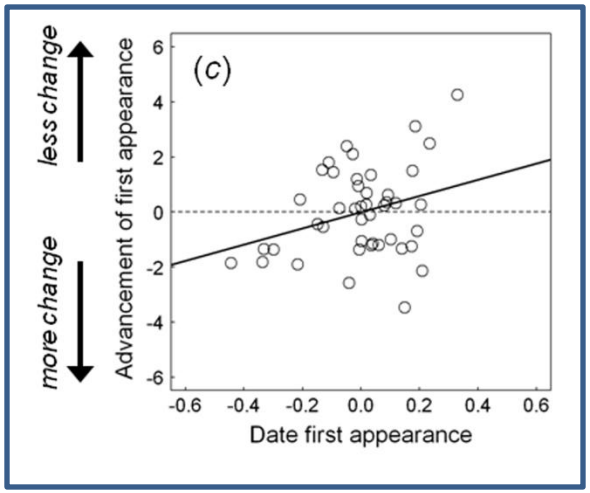


Species that have earlier annual dates of first appearance advance more

‘Significant’ predictors ($p < 0.05$, full model of all terms from best-fitting models; type III SS)







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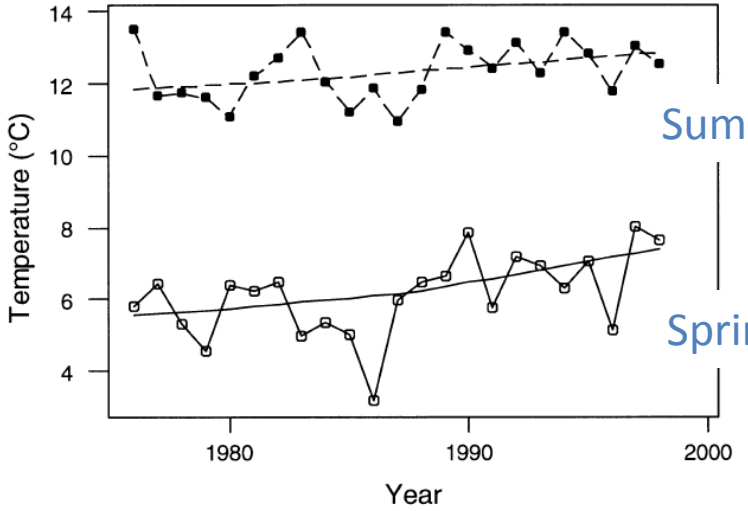

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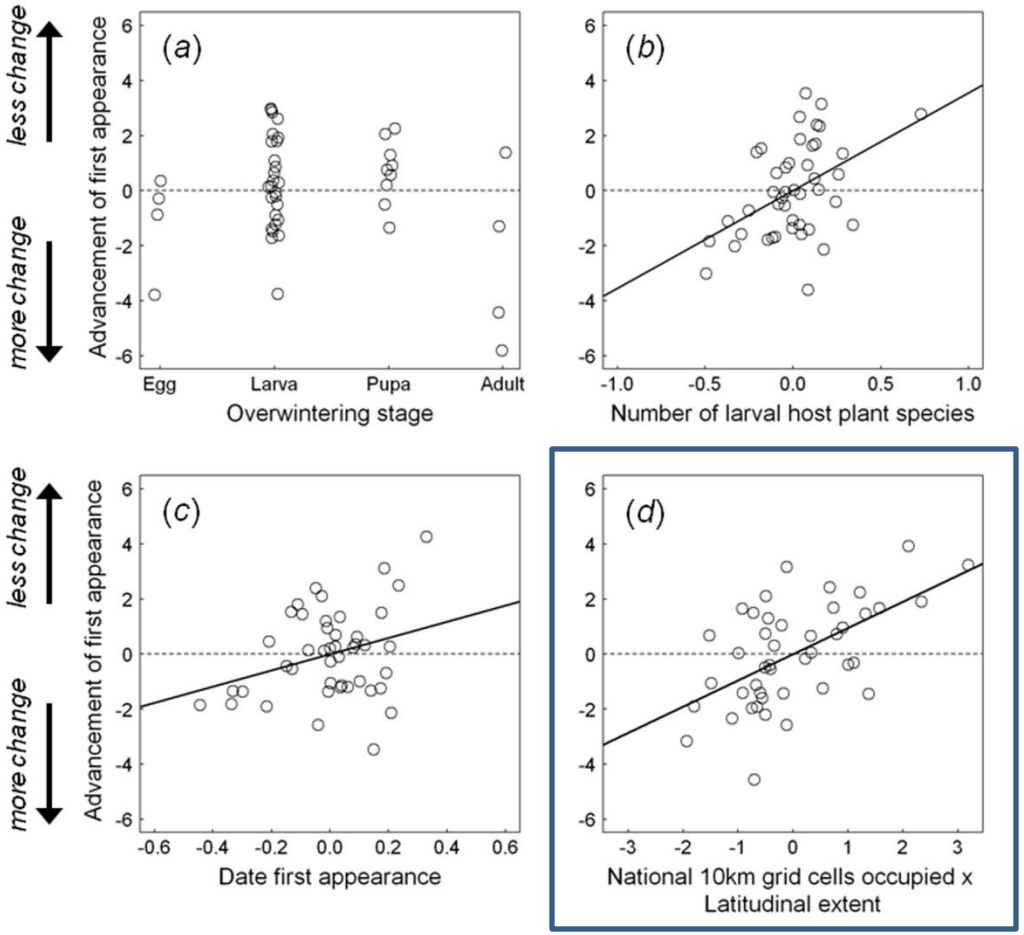
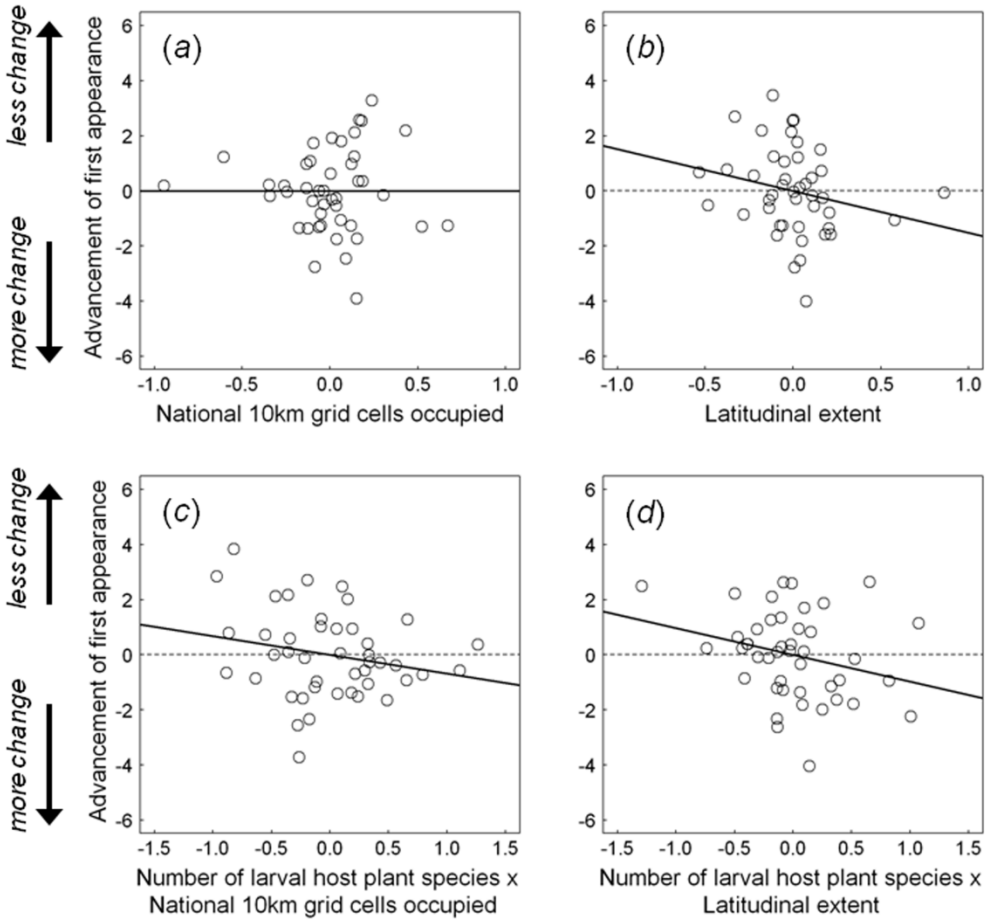


Species that occupy less habitat advance more

‘Non-significant’ predictors ($p < 0.05$, full model of all terms from best-fitting models; type III SS)



Implications

- Basic research
  - Identifies patterns between phenology & life history / species-level traits
  - Suggests testable hypotheses for the bases of these patterns
    - Especially need to link magnitude of phenological response with performance
- Applied research & Conservation
  - Identify those species that will respond most strongly to climate change
    - UK butterflies
    - Other species with particular life histories

Acknowledgements

- Univ. North Carolina collaborators
  - Alicia Frame, Ryan Martin, Lauren Buckley

- UKBMS and volunteers

Volunteer-based ant sampling

- North Carolina State University
  - Rob Dunn lab / Andrea Lucky (alucky@ncsu.edu)

- 'Ants in your Backyard' / citizen science program
  - Baiting for ants in your yard and house
  - Sending samples to be processed in the Dunn lab