

Differential seasonal shifts: climate change leads to ecological relationship problems

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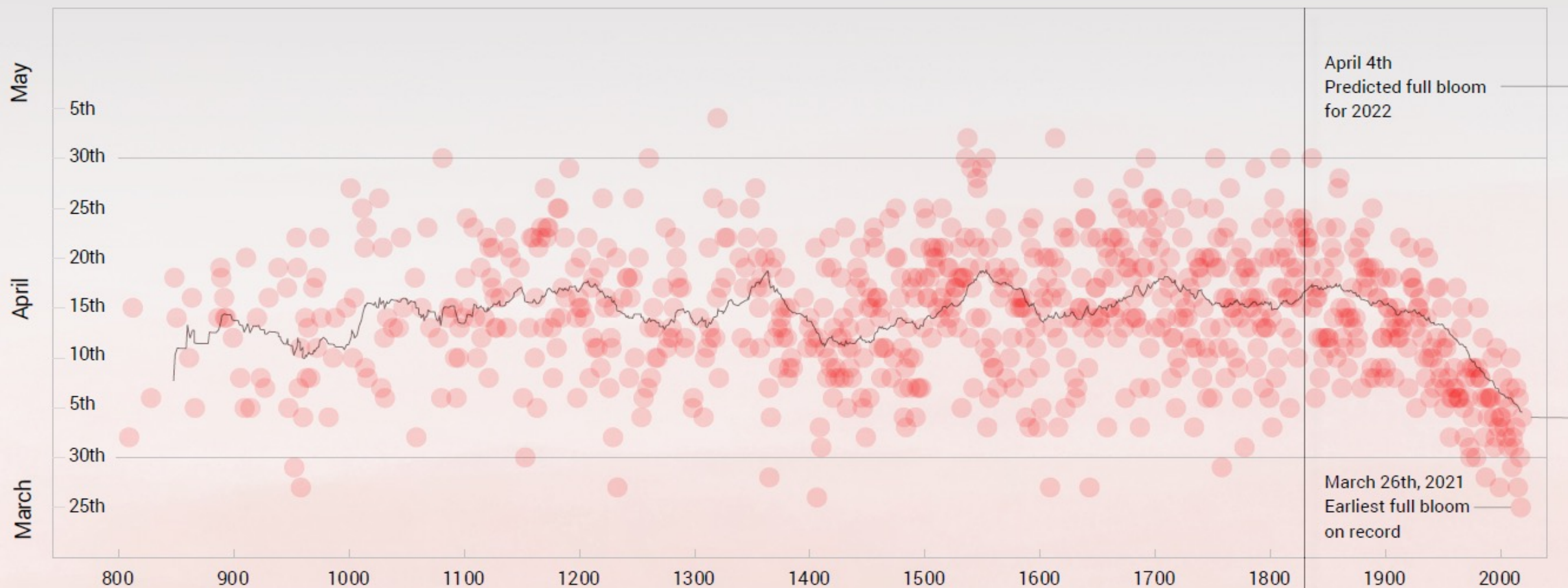


Józef Chełmoński, Bociany, 1900

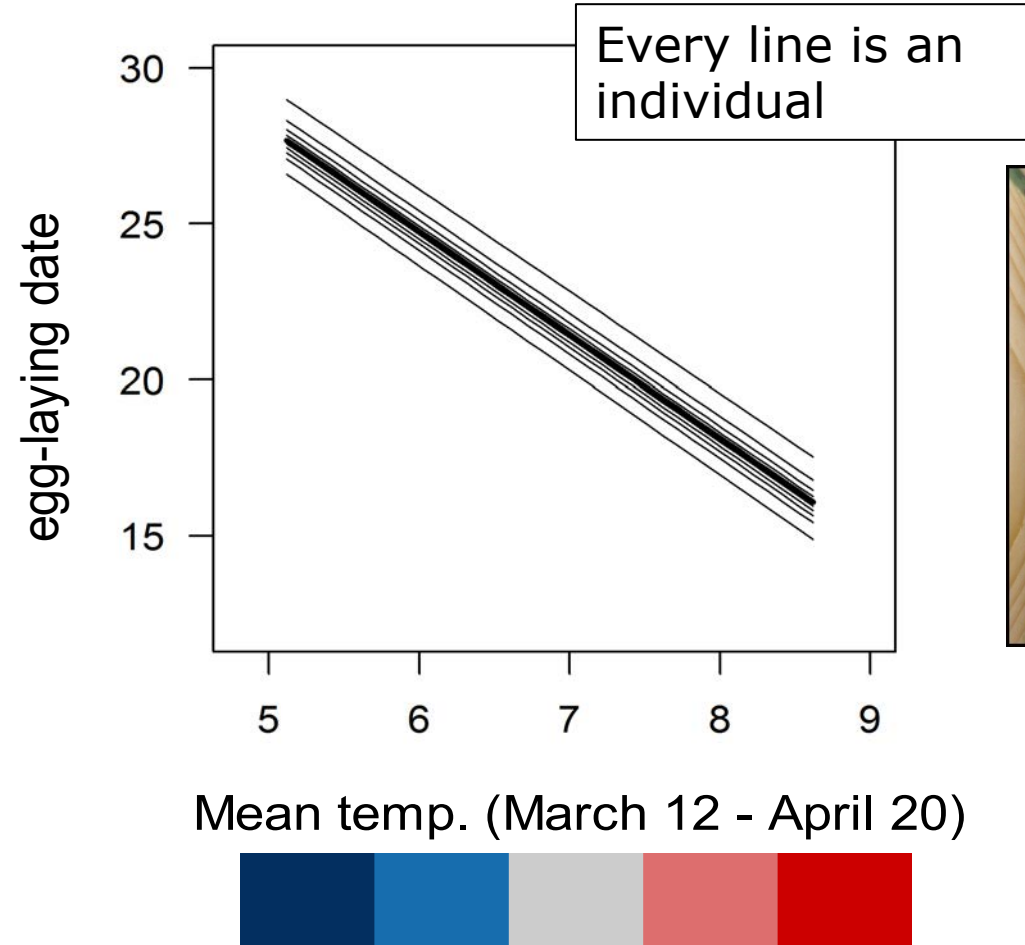
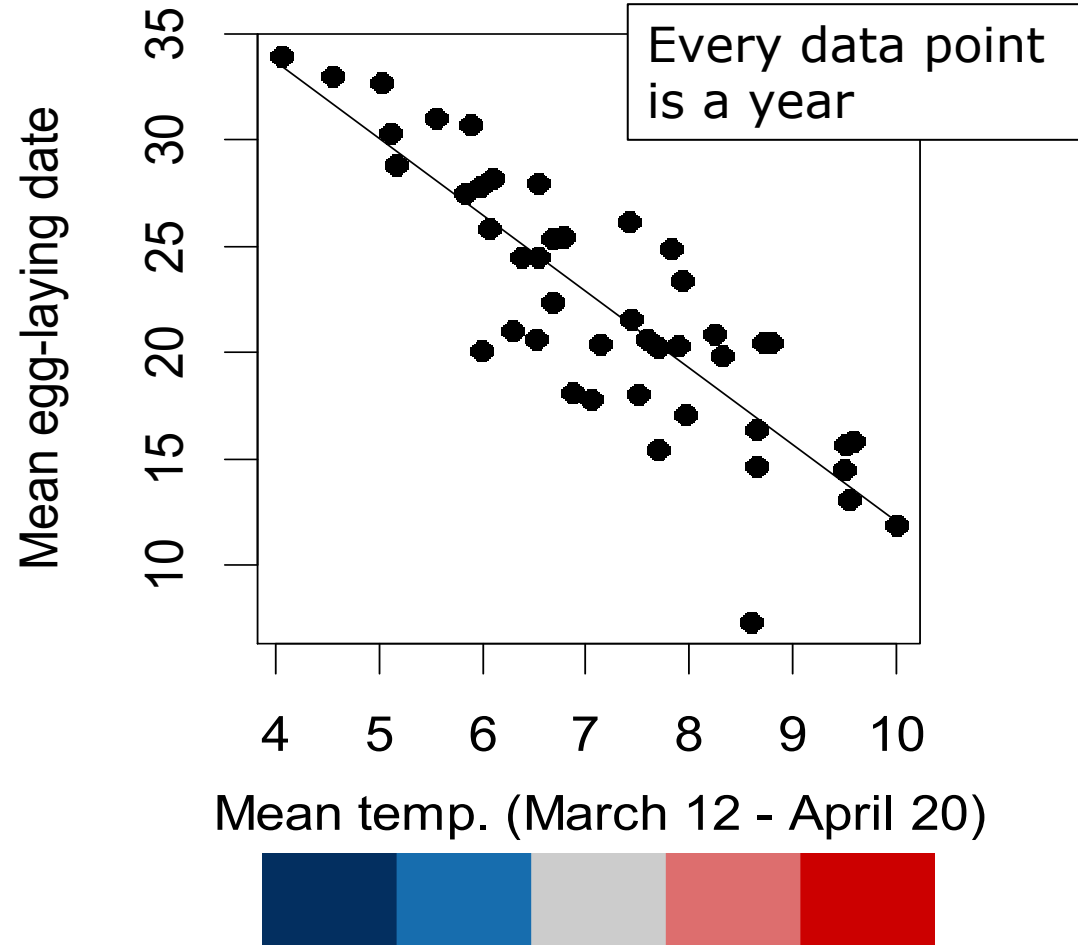


Blooming of cherry blossom over 1,200 years

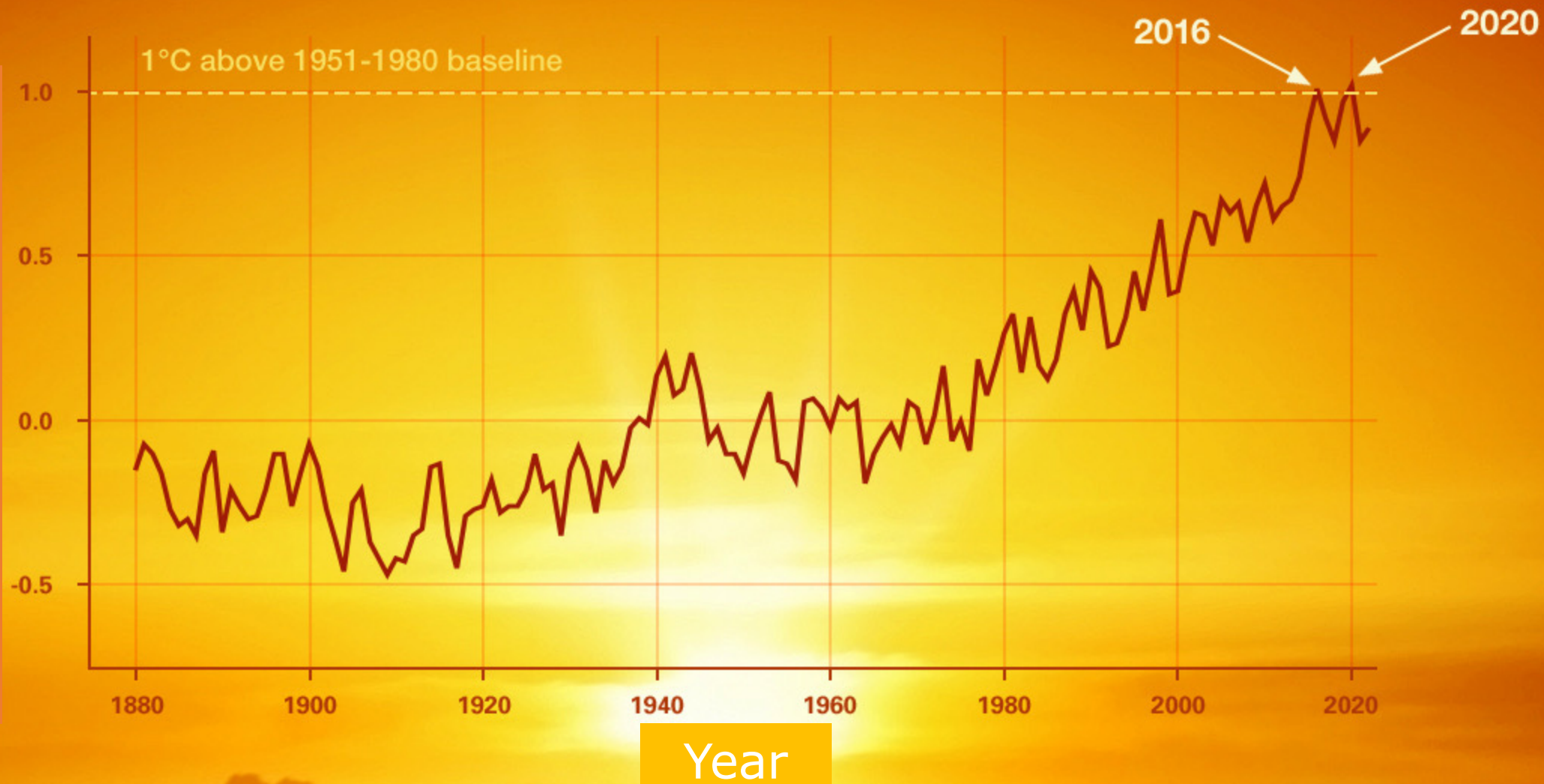
Trendline is 50-year moving average



Phenology is temperature dependent



Yearly temperature
anomalies from the
1951-1980 mean

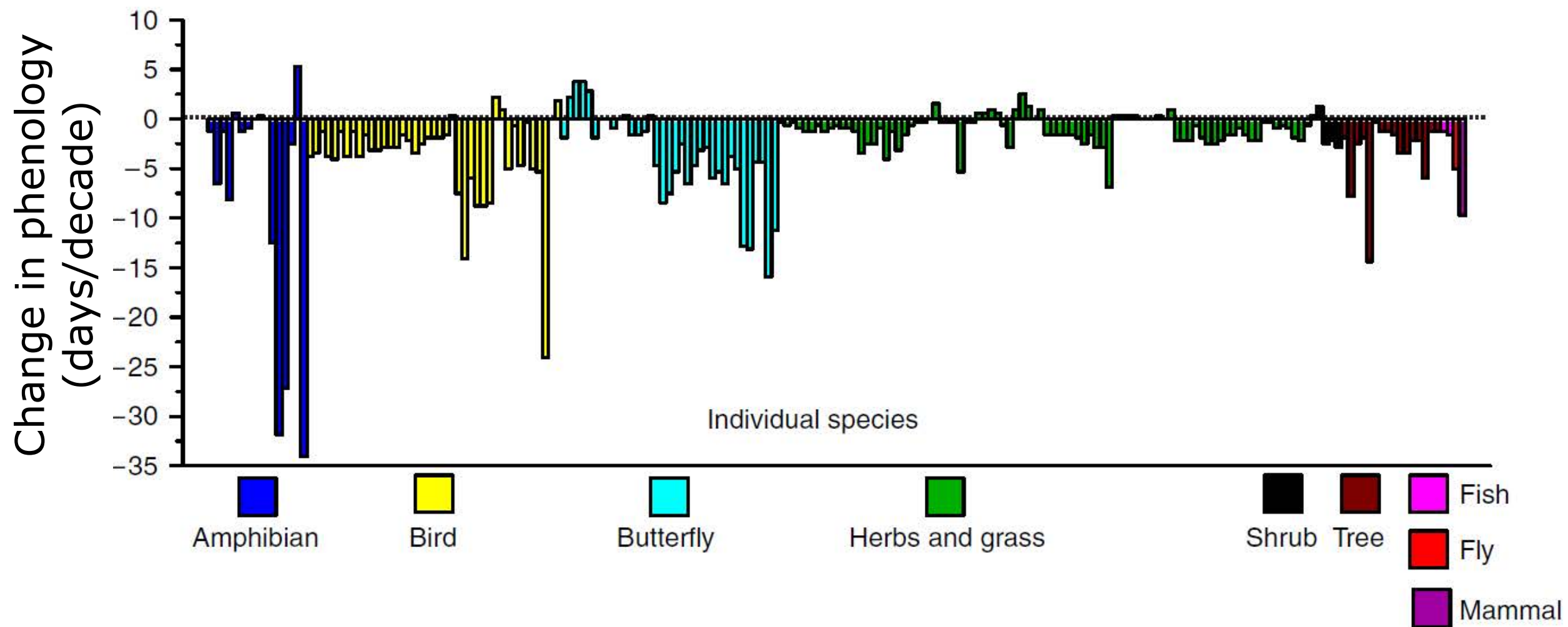


Phenology is temperature dependent

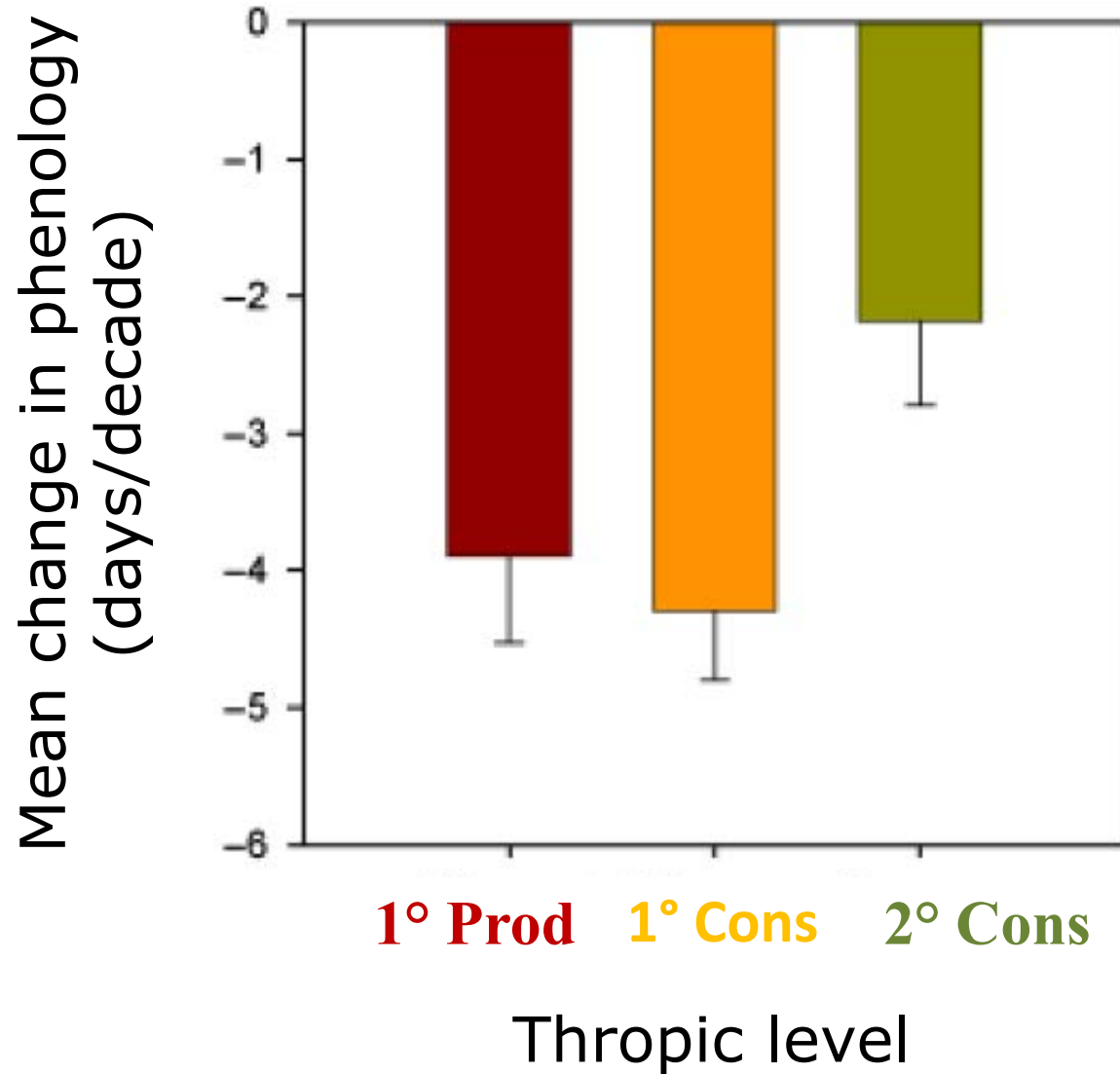
Global climate change leads to higher temperatures

Phenology is advancing

Shifts in phenology



Shifts in phenology



2° Cons



1° Cons



1° Prod



Thackeray et al. (2010) GCB;
Visser & Both (2005) Proc R Soc B

Phenology is temperature dependent

Global climate change leads to higher temperatures

Phenology is advancing

But not all phenology is advancing at the same rate

This leads to phenological mismatches

Climate change leads to ecological relationship problems



Roe deer



Caribou

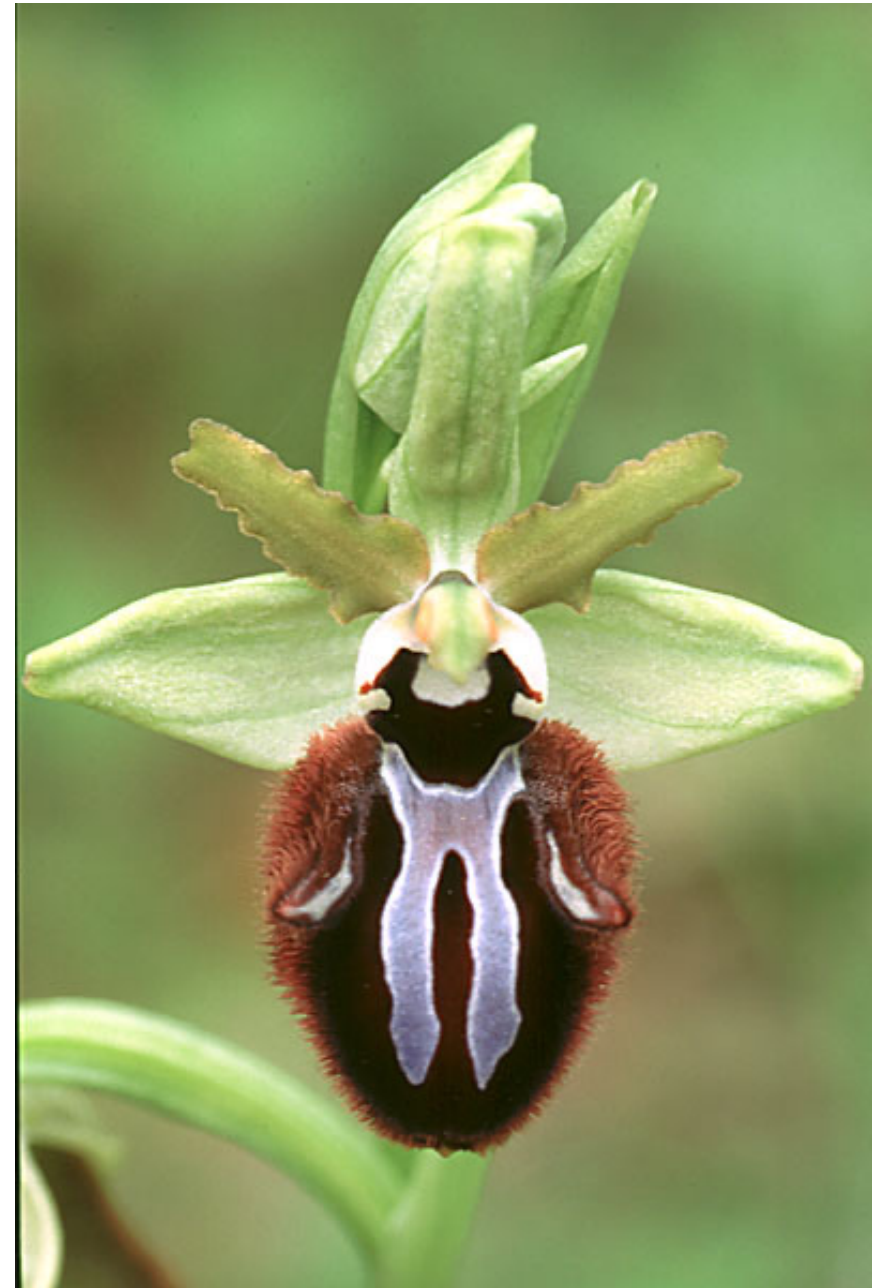
The vegetation shift its phenology (growing season) stronger than the phenology of roe deer, and of caribou (birth date)

The bees shift their phenology (flight date) stronger than the phenology of the orchid (flowering time)

Robbirt et al Curr Biol 2014



Andrena nigroaenea

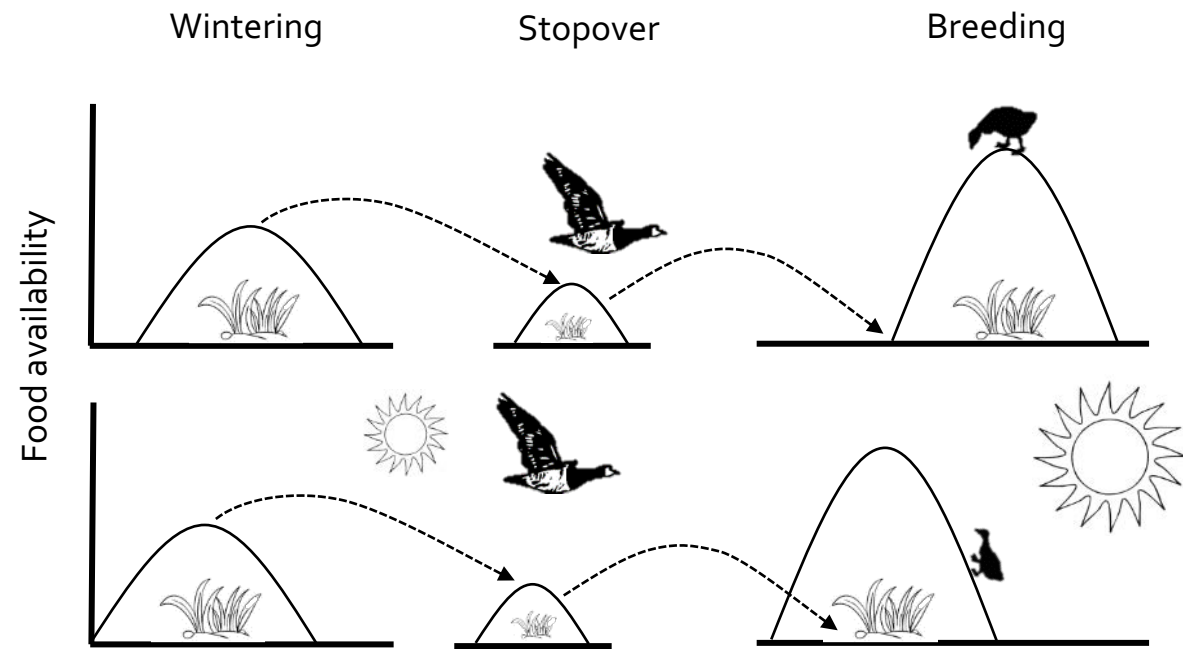


Ophrys sphegodes



The phenology (arrival date) of the Barnacle Geese does not keep up with the advancement of the phenology of their food in their breeding grounds

Lameris et al. Current Biology 2018





The phenology (arrival date) of the American Robin shift stronger than date of snow melt

Inouye et al. PNAS 2000

1. Why does climate change lead to differential shift in phenology?
2. Will populations adapt to climate change through evolutionary changes?
3. If populations do not adapt fast enough to climate change, will they decline?

A simplified food chain



*Quercus
robur*

Bud burst



*Operophtera
brumata*

Egg hatching



*Parus
major*

Nestlings to feed

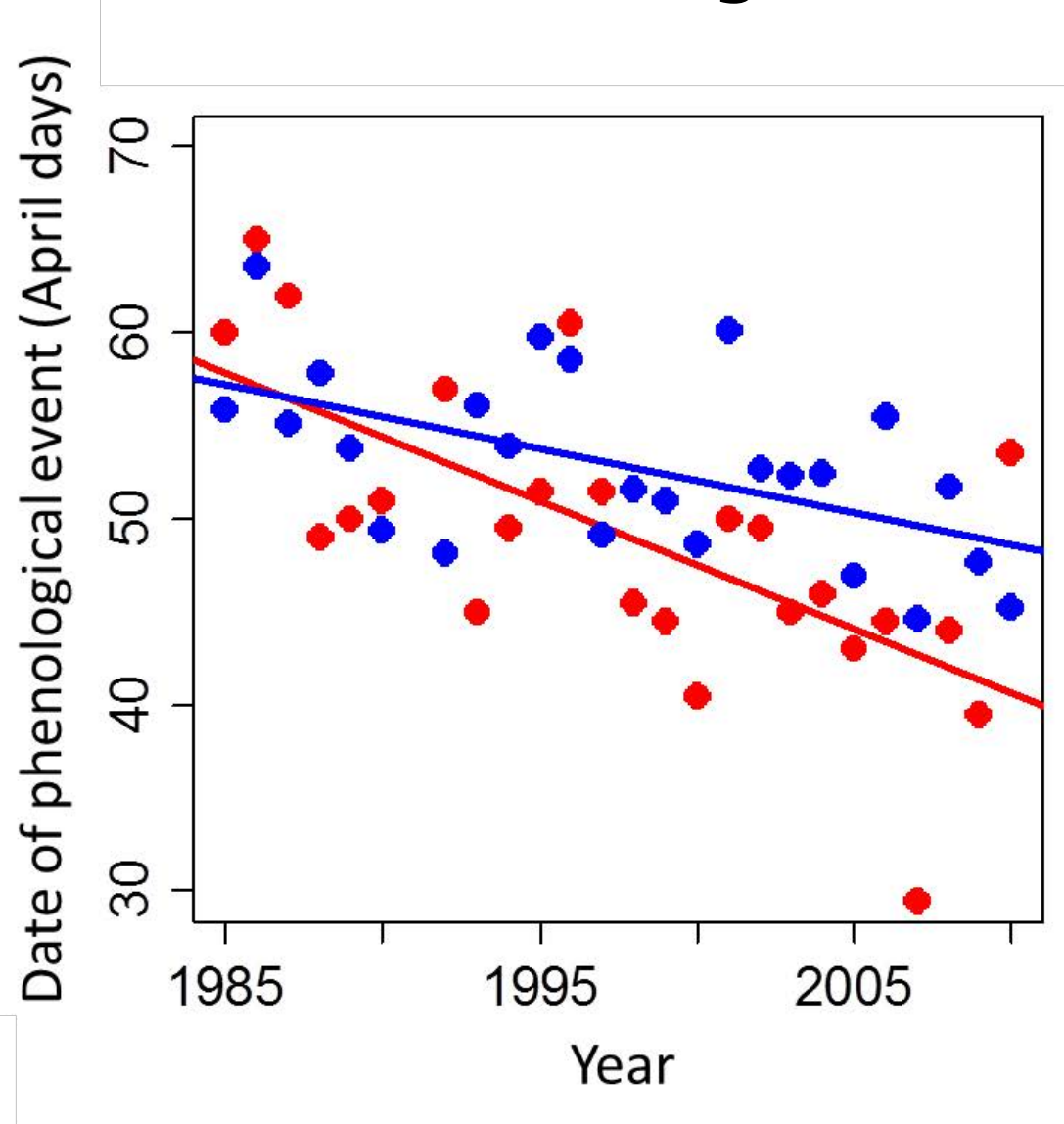


*Ficedula
hypoleuca*

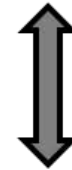
Why does climate change lead to differential shift in phenology?

Shifts in seasonal timing are unequal across trophic levels

Classical story



Slope = -0.35
days / year



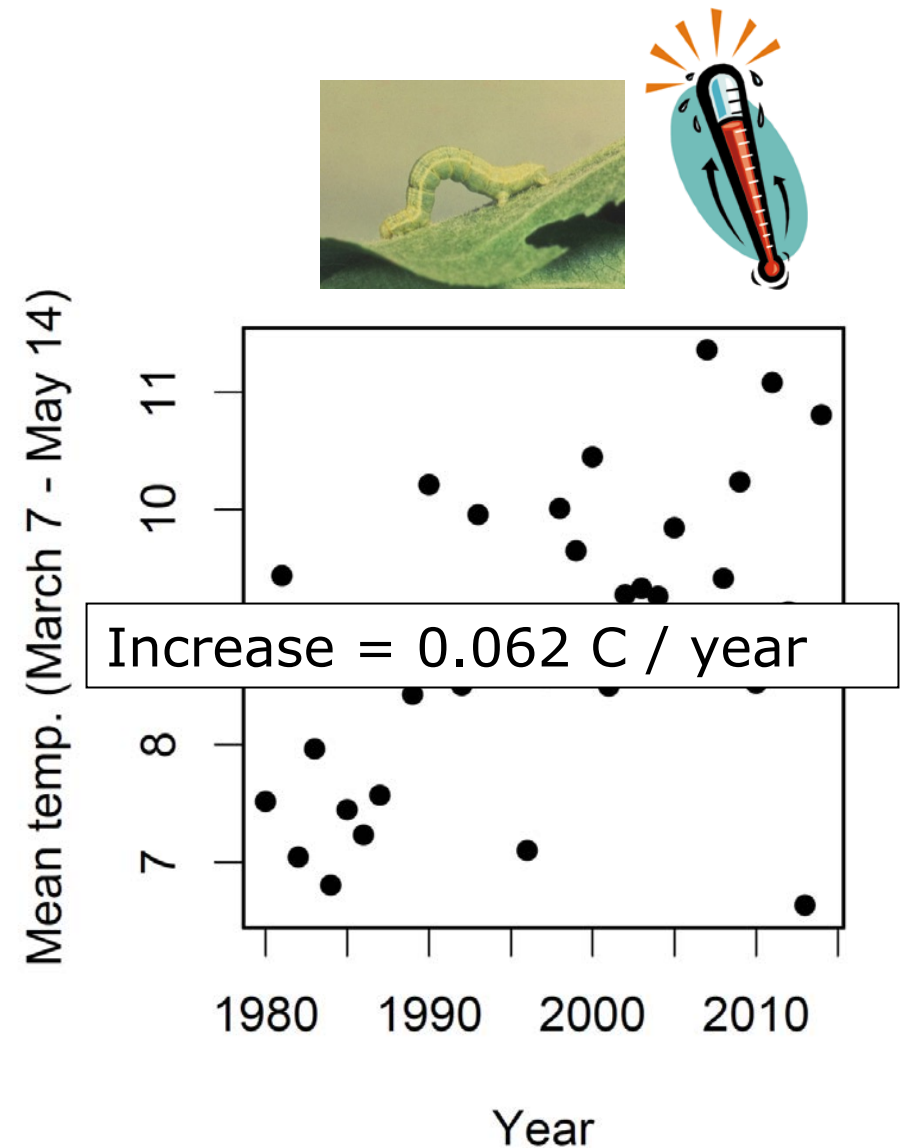
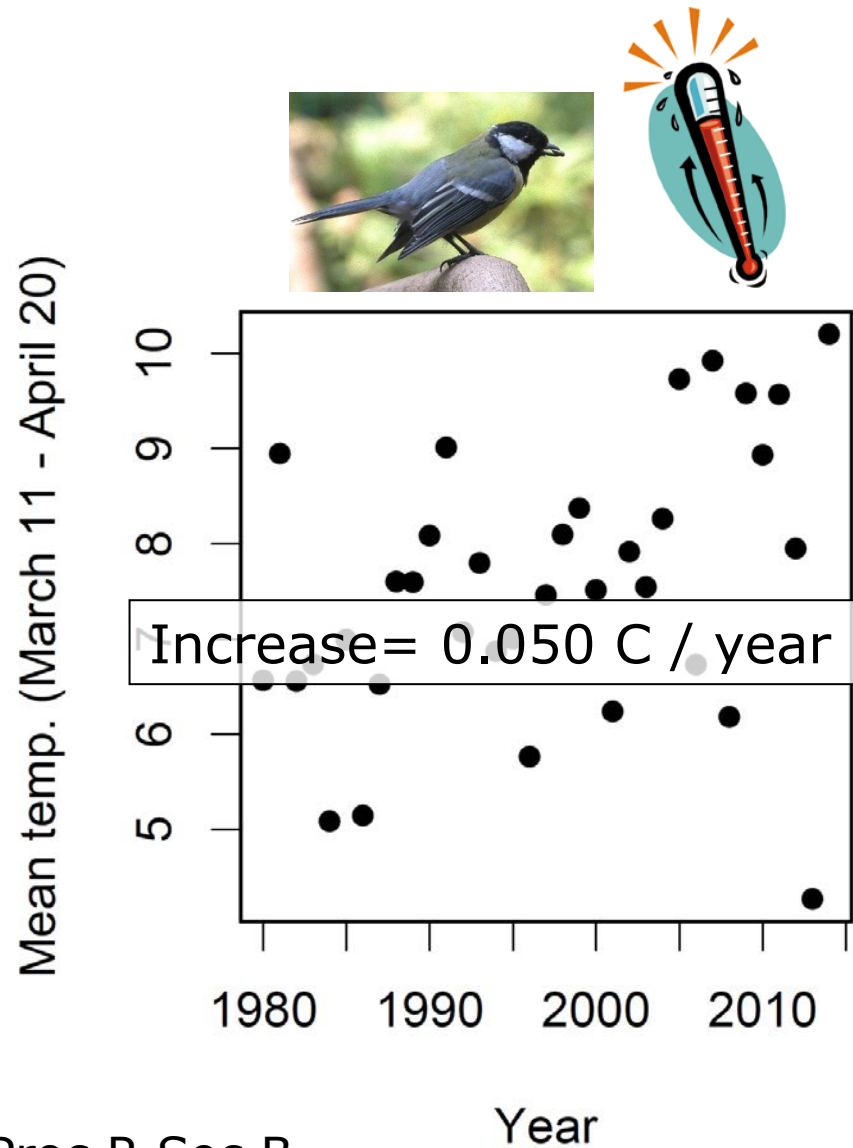
Phenological mismatch

Slope = -0.69
days / year



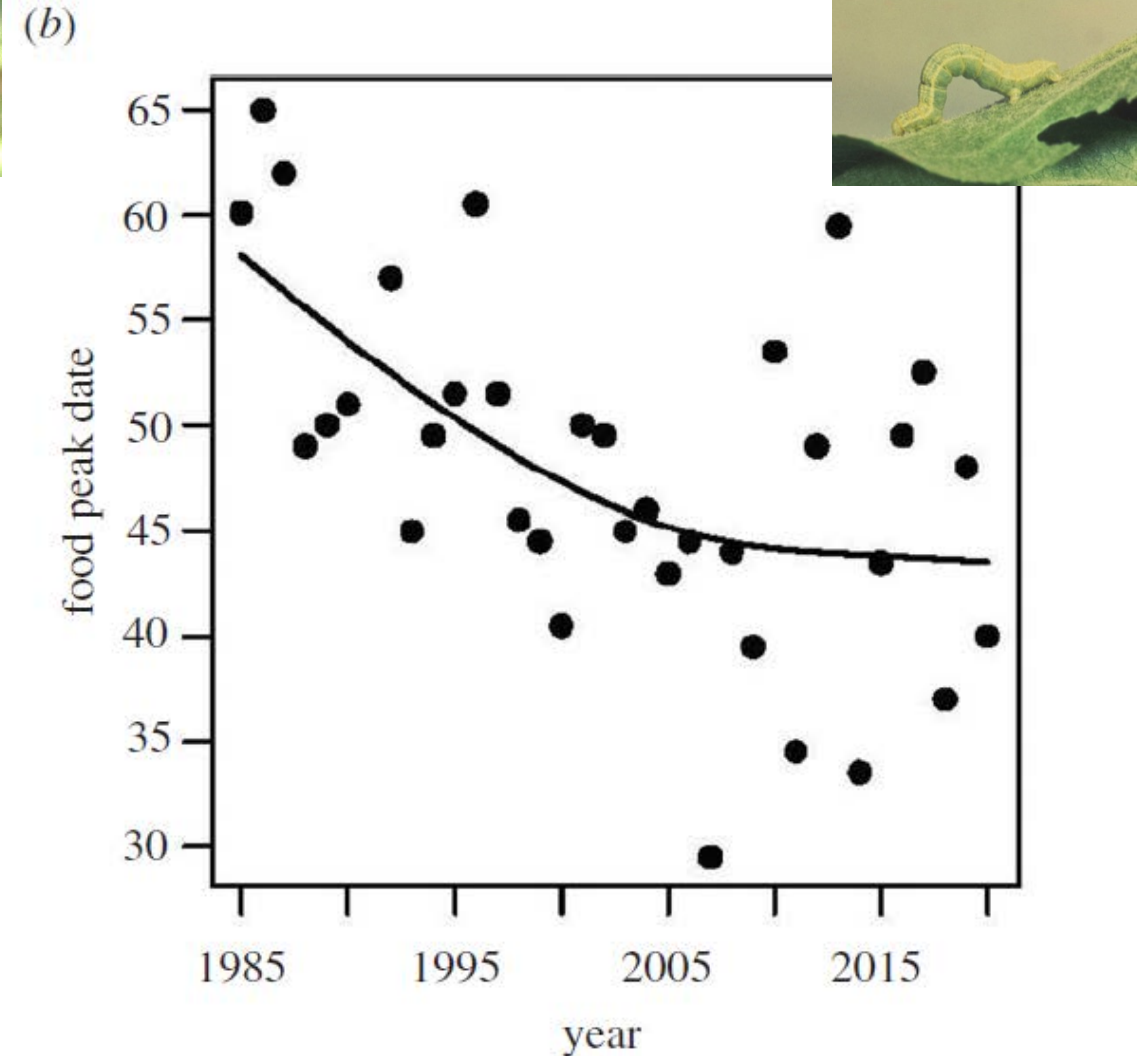
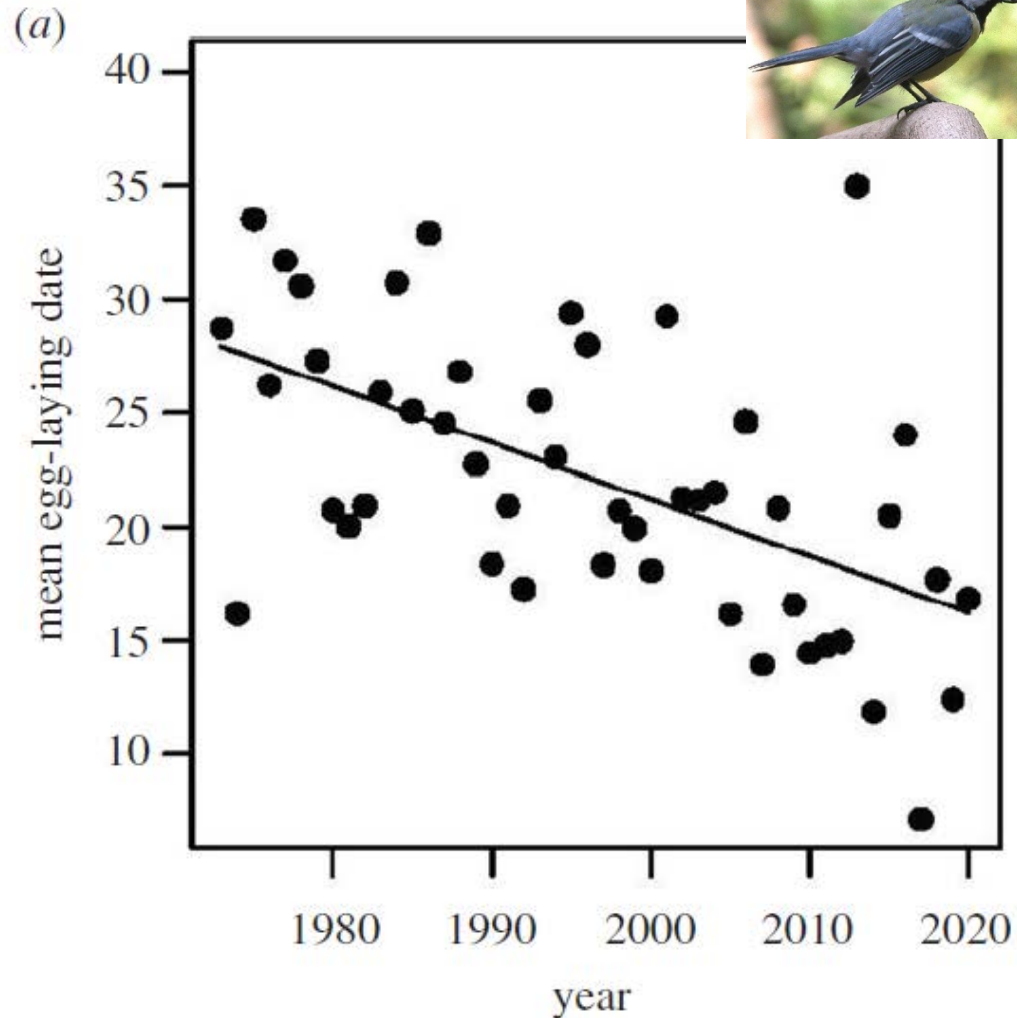
Climate change has led to a phenological mismatch

Classical story



Why does climate change lead to mismatches?

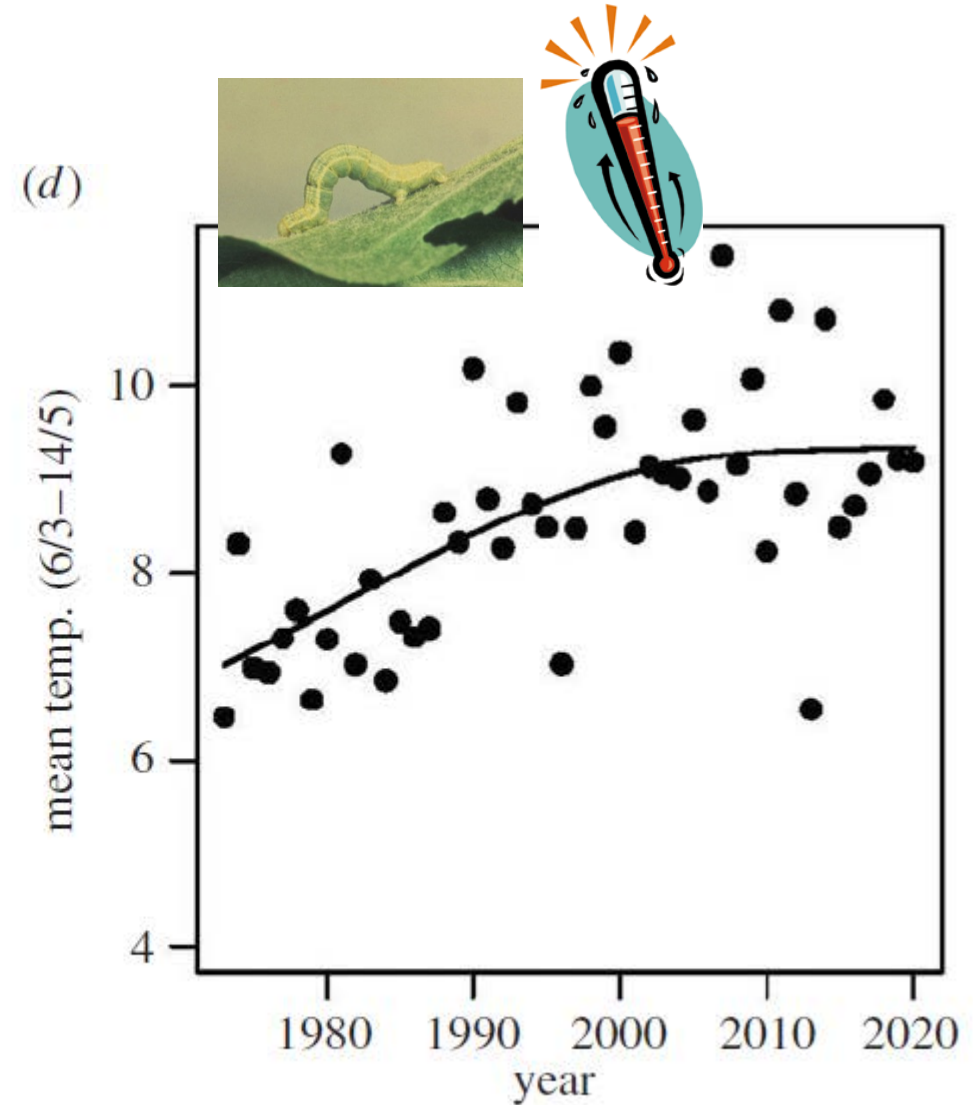
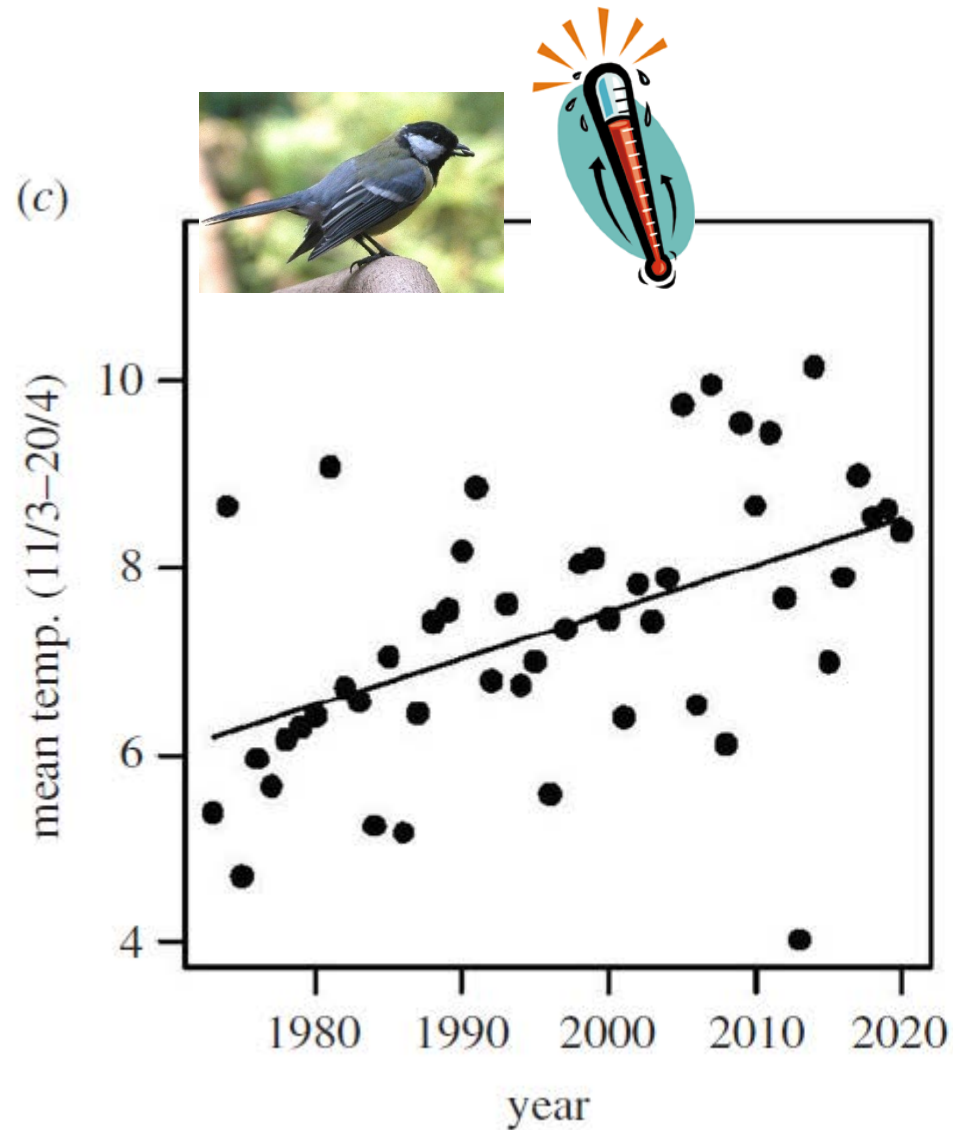
Recent finding



Visser et al. (2021) Proc R Soc B

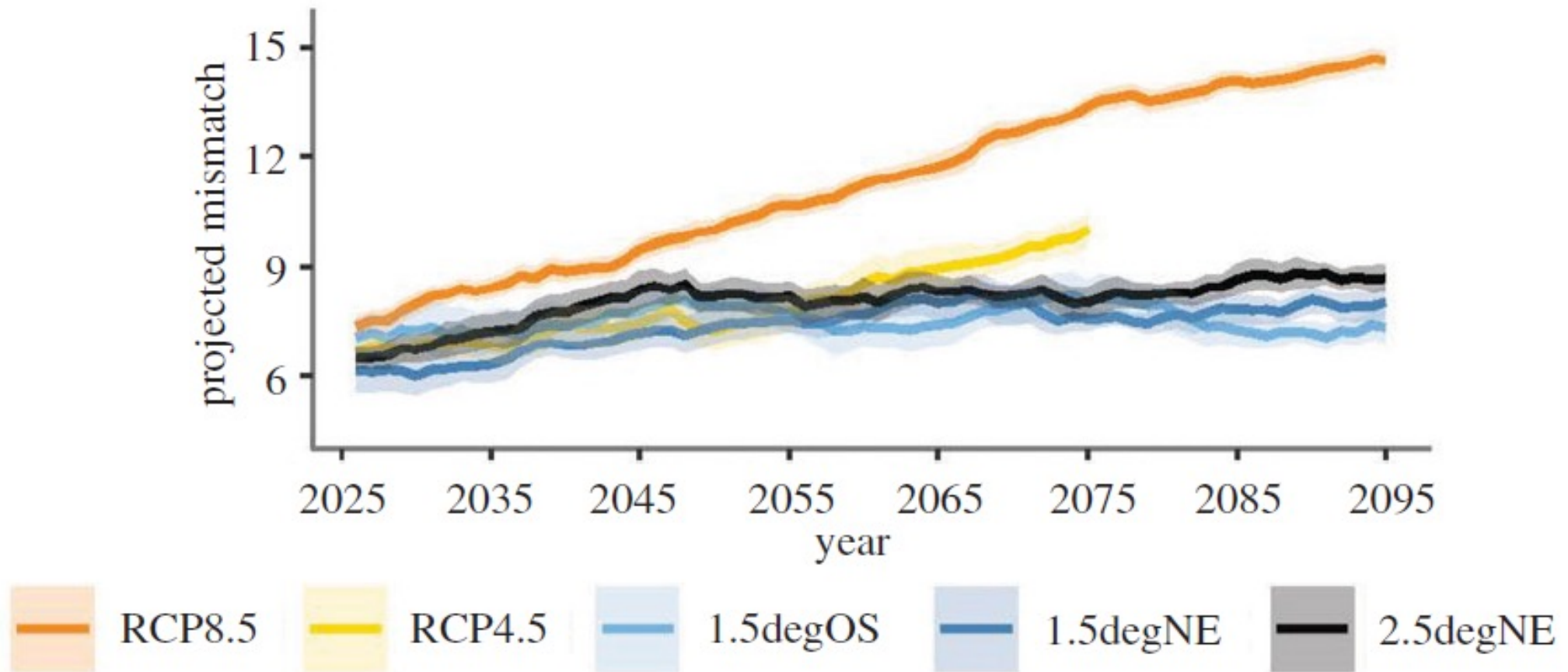
Why does climate change lead to mismatches?

Recent finding



Visser et al. (2021) Proc R Soc B

Why does climate change lead to mismatches?



Pied flycatchers arrive too late at the breeding grounds



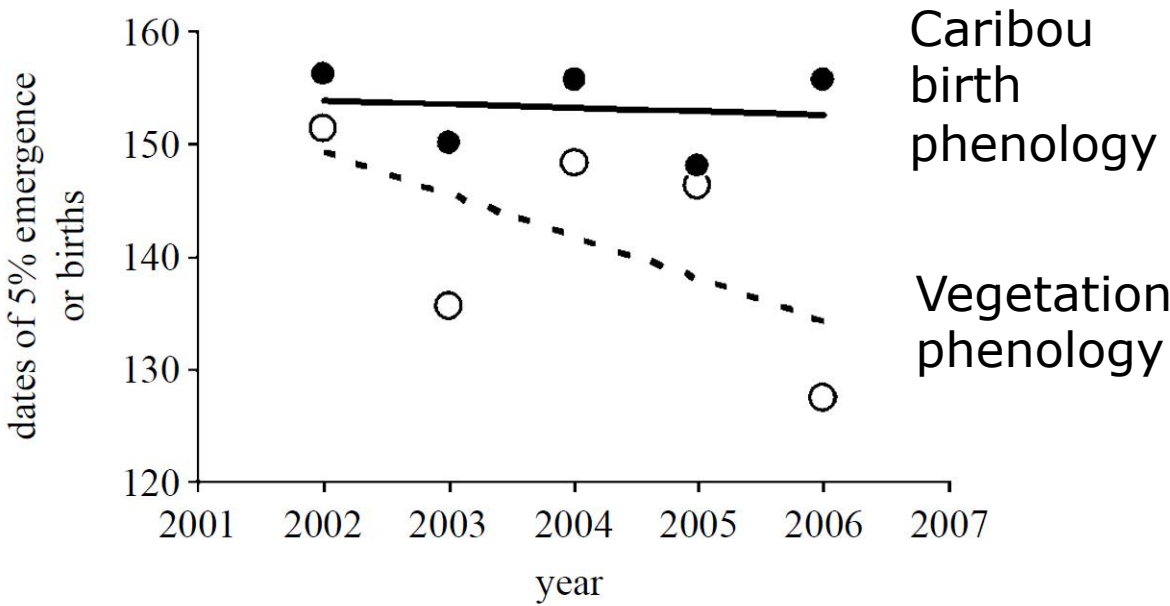
Both & Visser (2001)
Nature



Caribou's birth phenology depends on photoperiod



Post & Forchhammer (2008) Phil Trans B



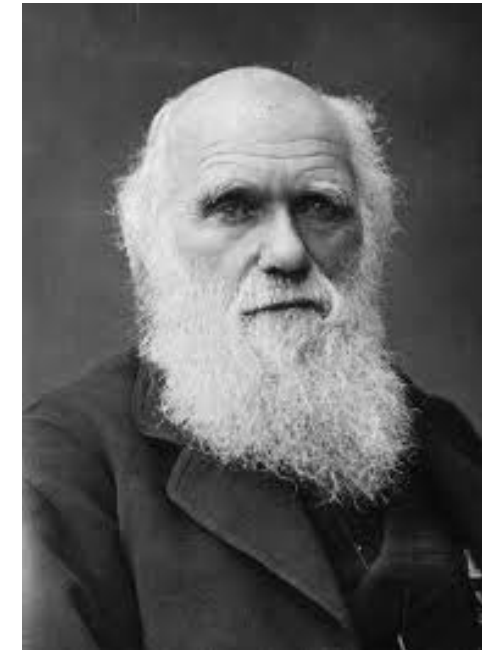
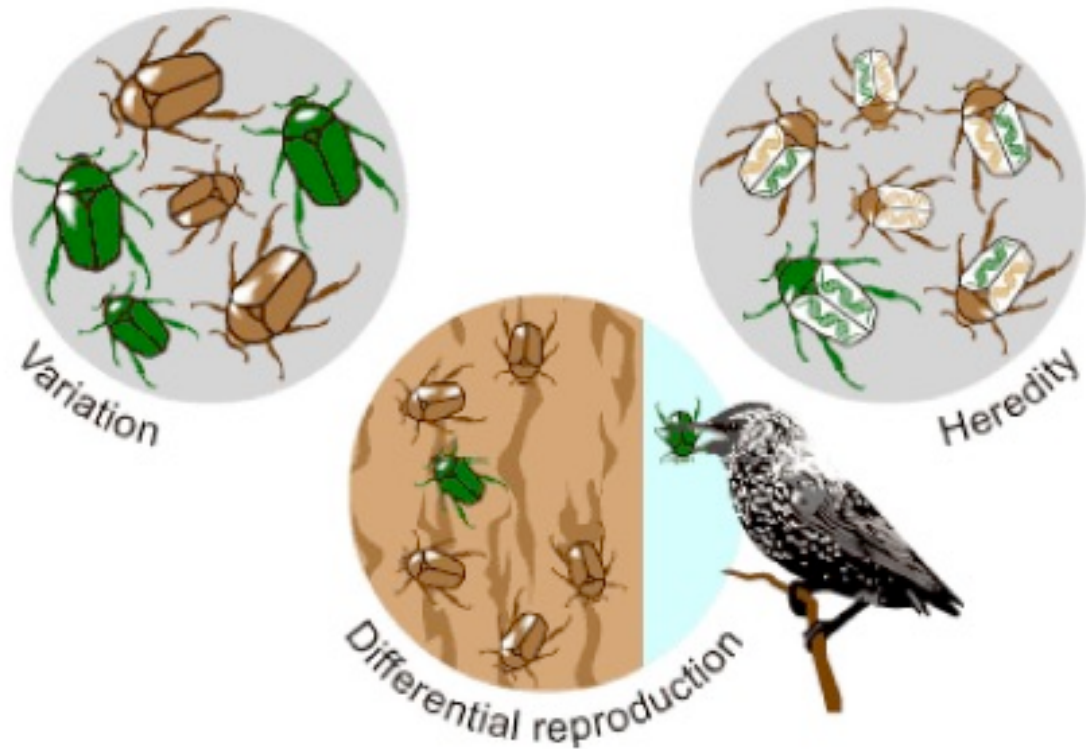
Why does climate change lead to differential shift in phenology?

Differences in sensitivity to photoperiod and temperature

Differences in the temperature window that affects phenology, and windows warm up at different rates

Differences in the rate of climate change in the wintering and breeding areas

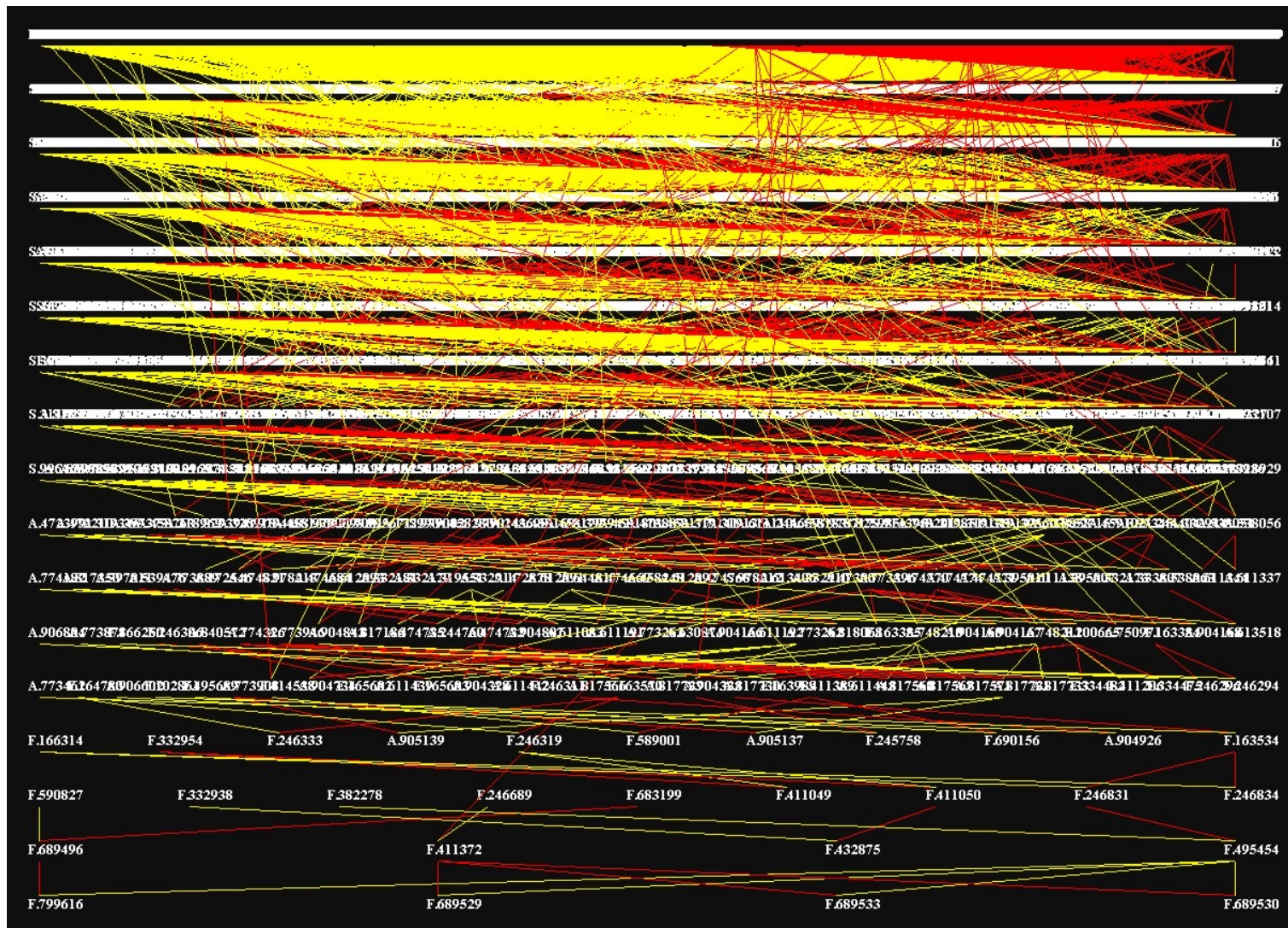
Will populations adapt to climate change through evolutionary changes?



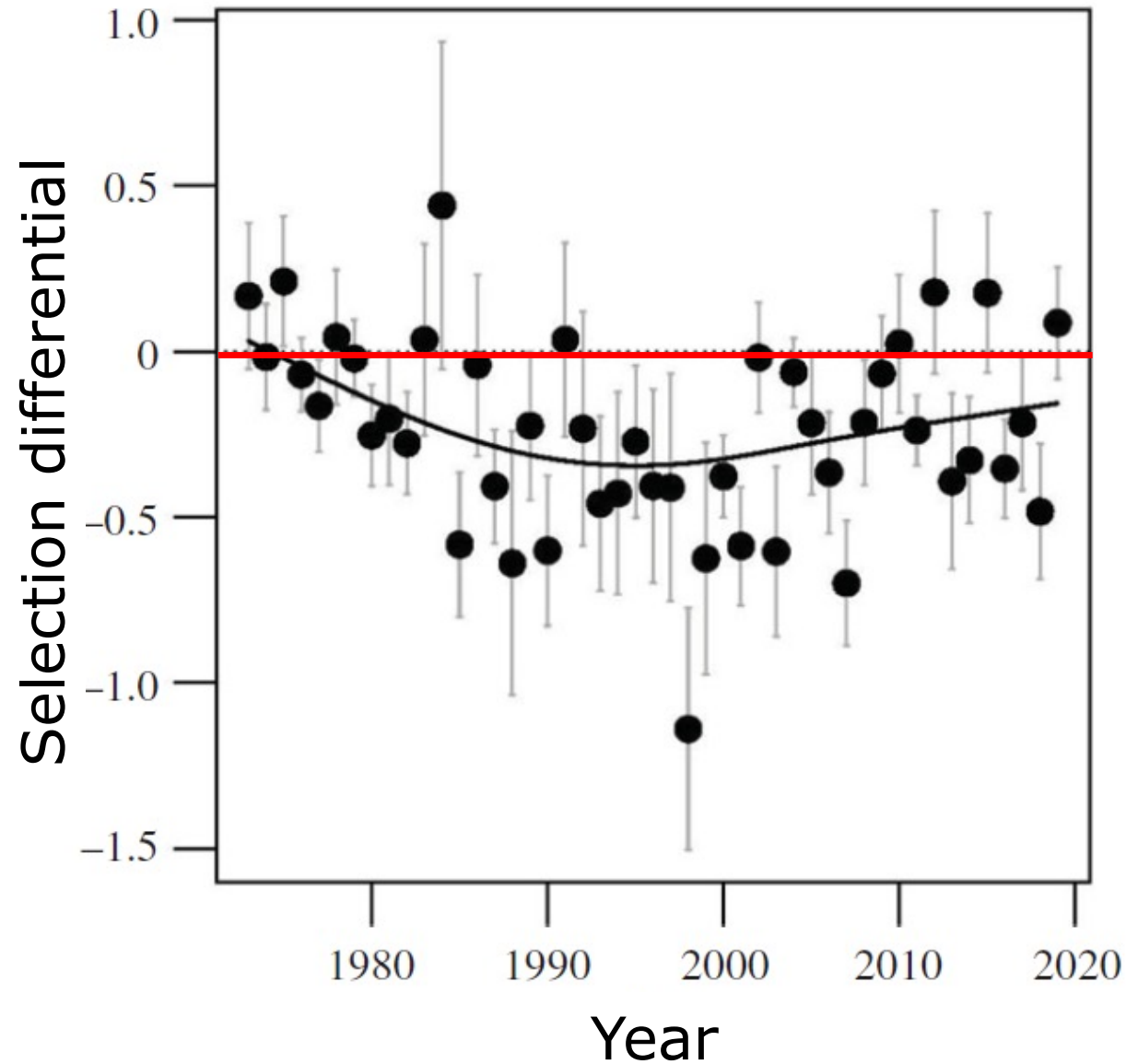
C.R. Darwin
(1809–1882)

Variation, differences in fitness, and heredity leads to micro-evolution

Pedigree of the Hoge Veluwe great tits



Heritability
of laying
date = 0.17

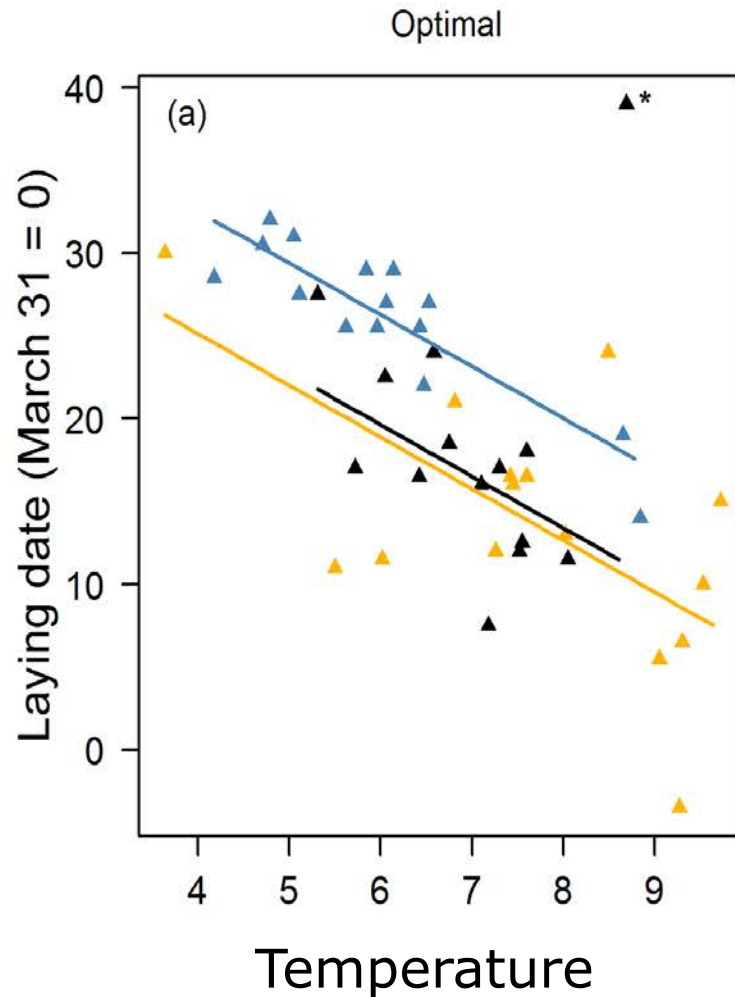


*Late laying
birds have
higher fitness*

*Early laying
birds have
higher fitness*

There is
selection for
early laying

Will there be evolutionary rescue?

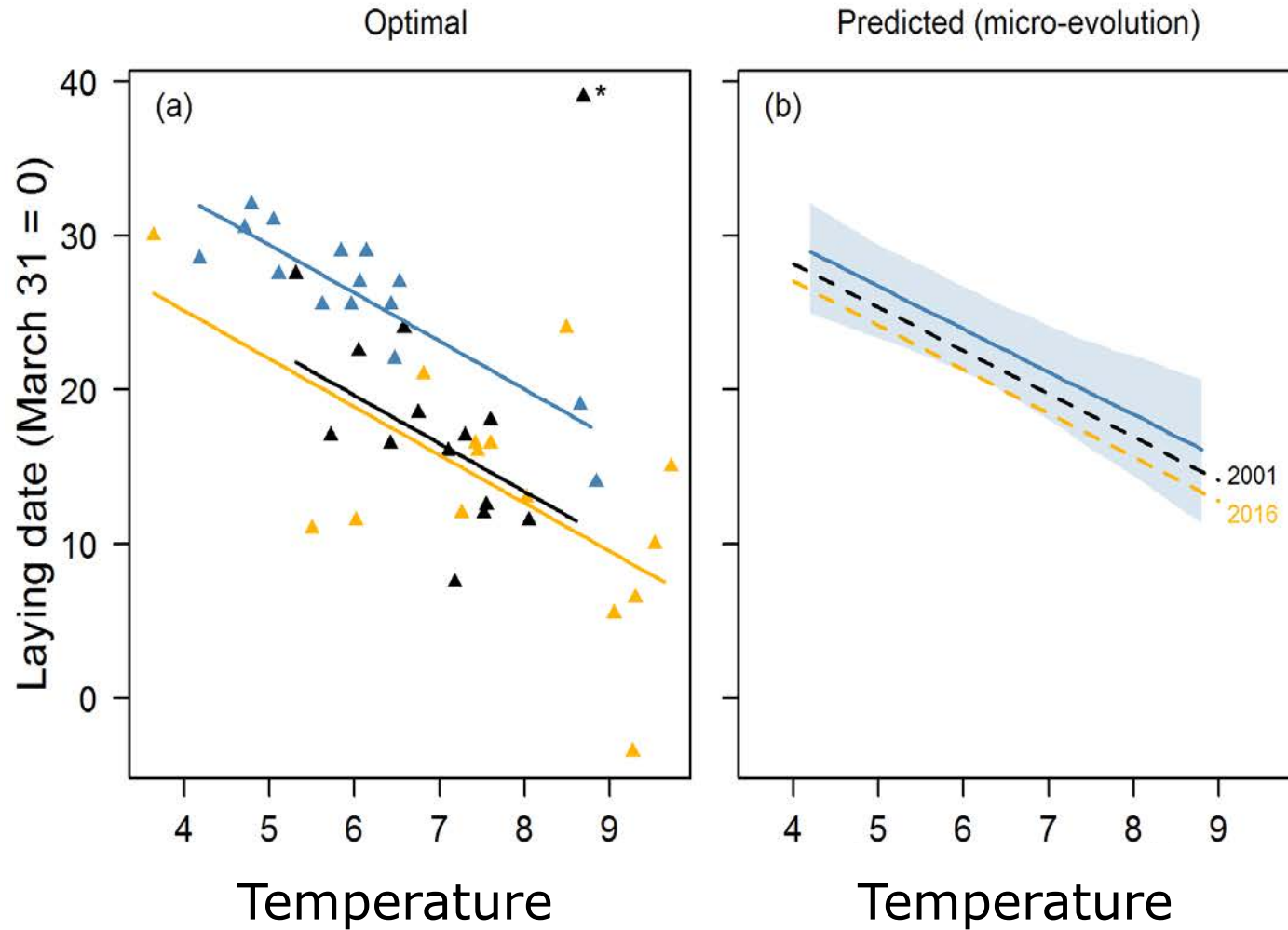


Optimal reaction norm (*i.e. perfect match between resource needs and resource availability*) in three time periods:

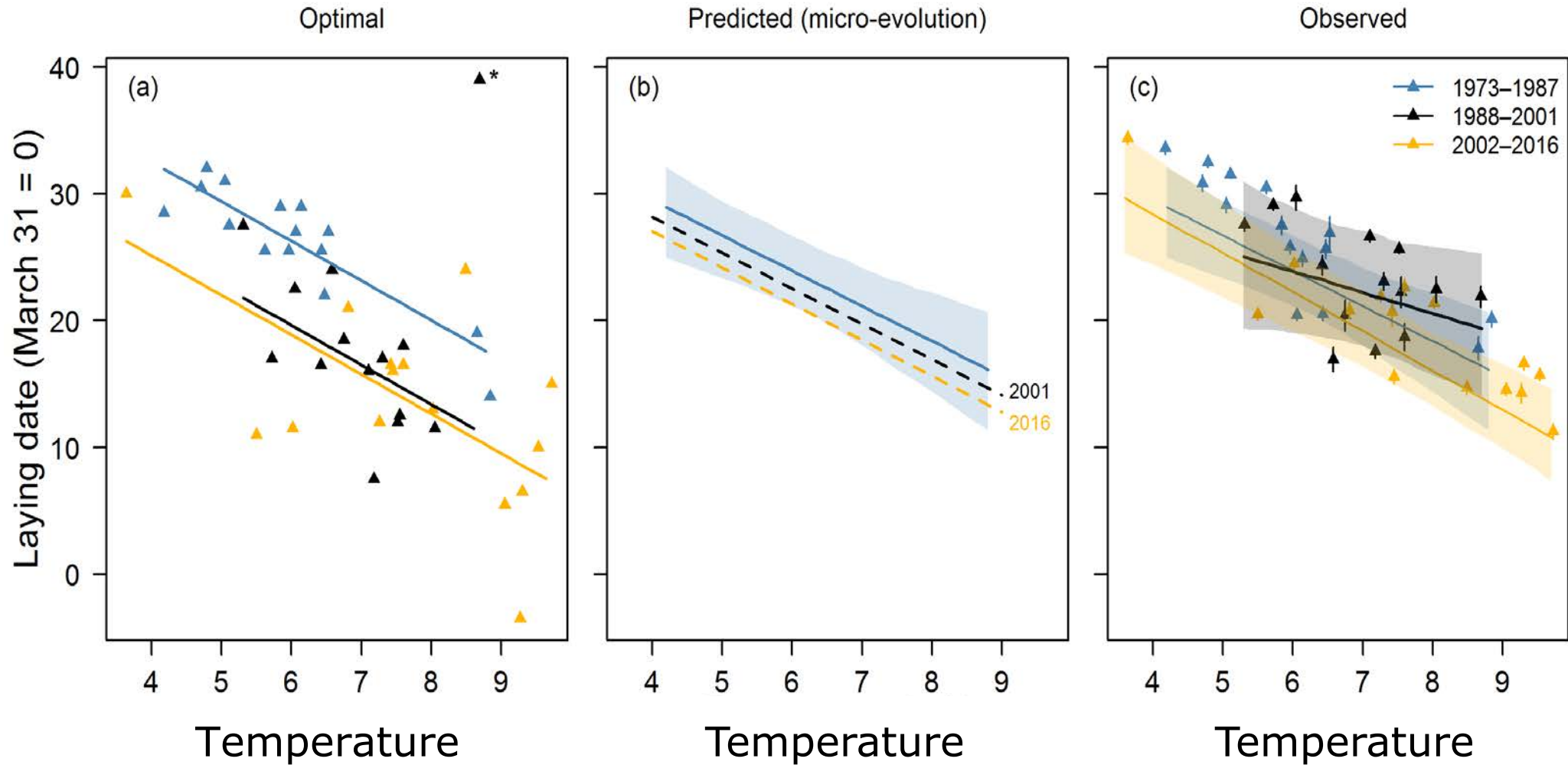
1973-1987 1988-2001 2002-2016

Shift in elevation from period 1 to period 3 is 8.5 days

Will there be evolutionary rescue?



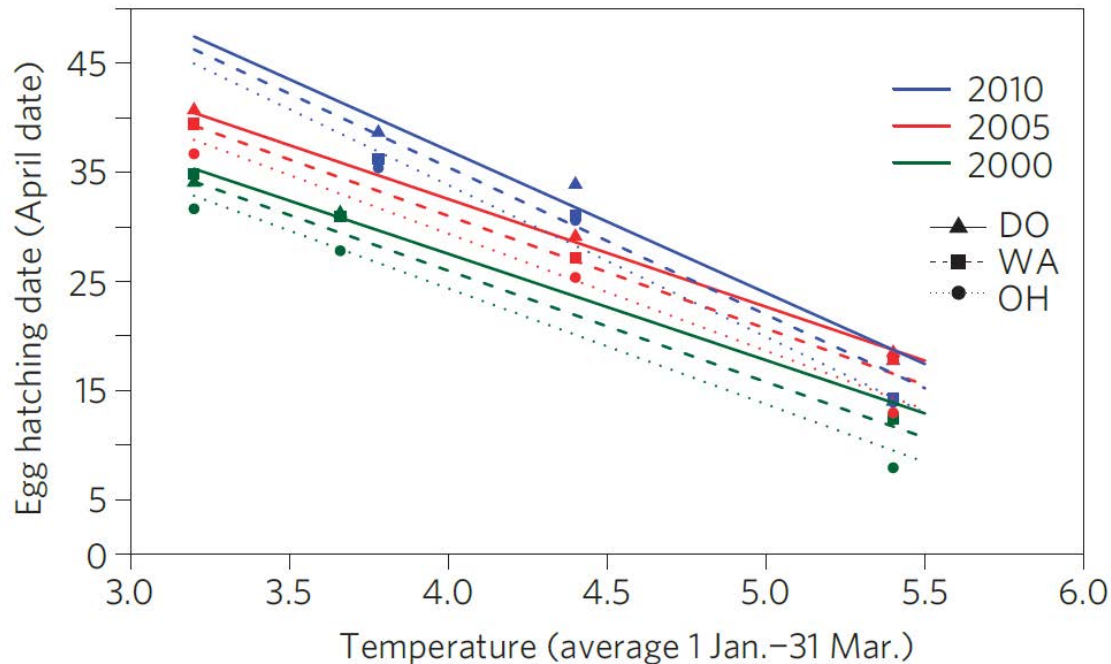
Will there be evolutionary rescue?



Winter moth egg hatching phenology has genetically changed



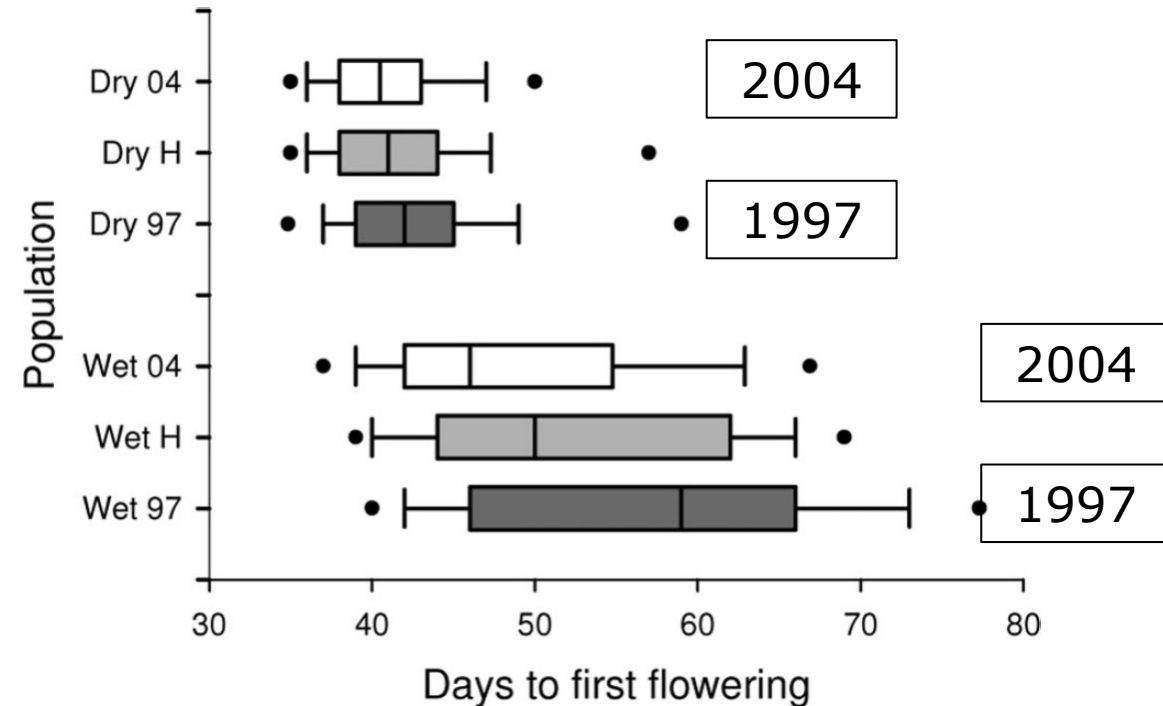
Van Asch et al.
(2012) Nature
Climate Change



Field mustard's flowering phenology has genetically changed



Frank et al.
(2007) PNAS



Will populations adapt to climate change through evolutionary changes?

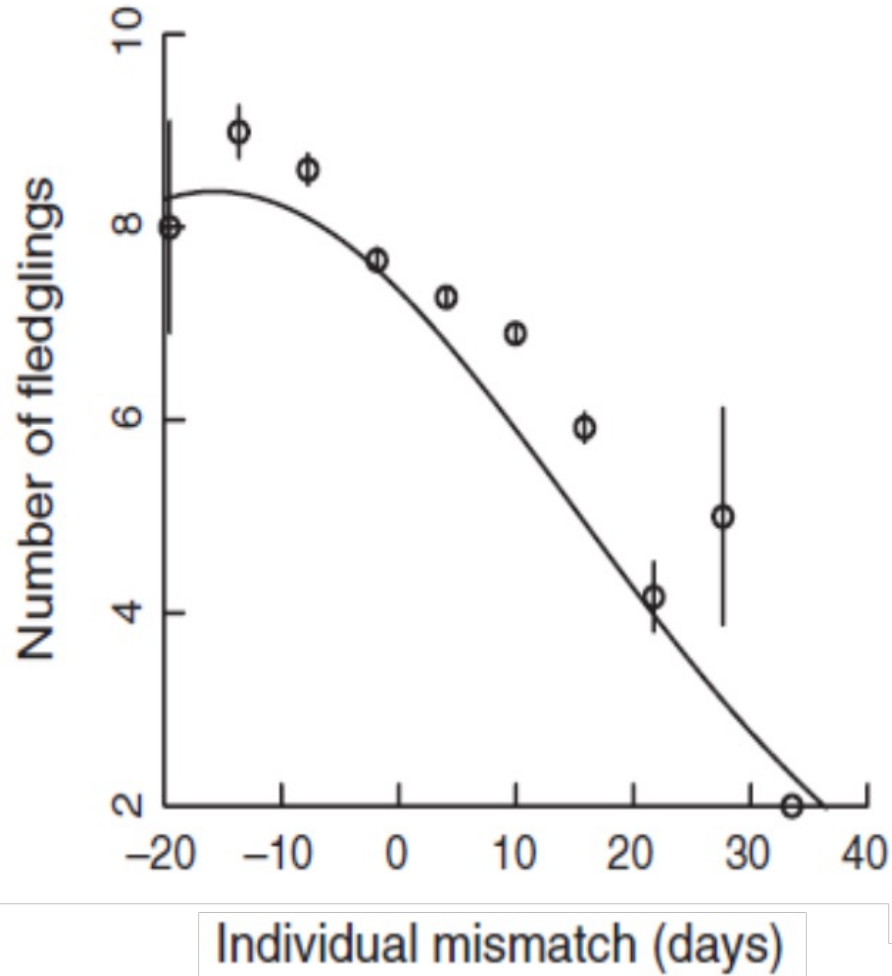
The will be evolutionary changes as phenology is heritable and there is selection for earlier or later phenology

But the rate of this micro-evolution will be too slow to keep up with climate change

Rate of climate change is now 50 times faster than historical warming rates

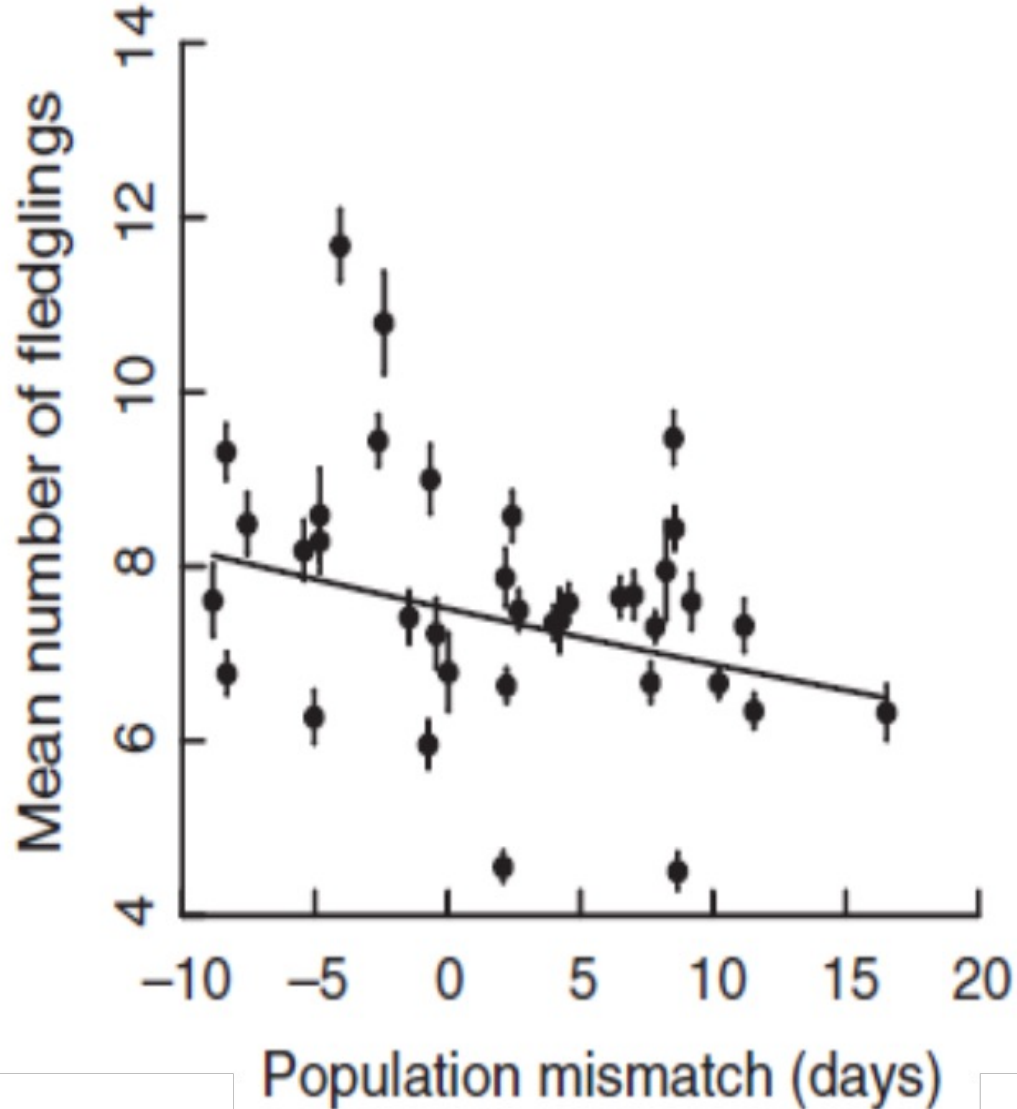
If populations do not adapt fast enough to climate change, will they decline?

Population consequences of mismatches



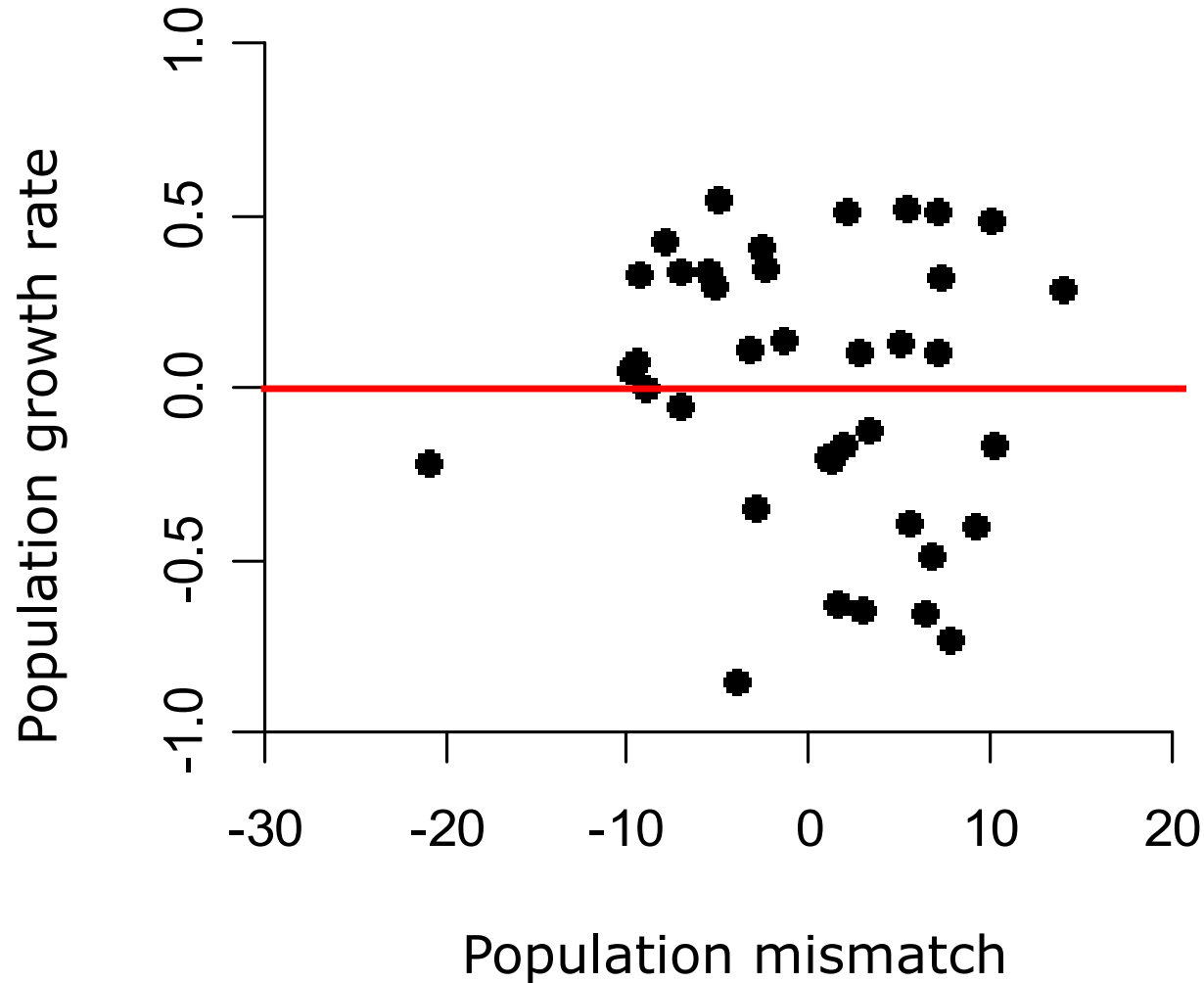
Individual mismatches lead to reduced number of offspring produced, a major component of fitness

Population consequences of mismatches



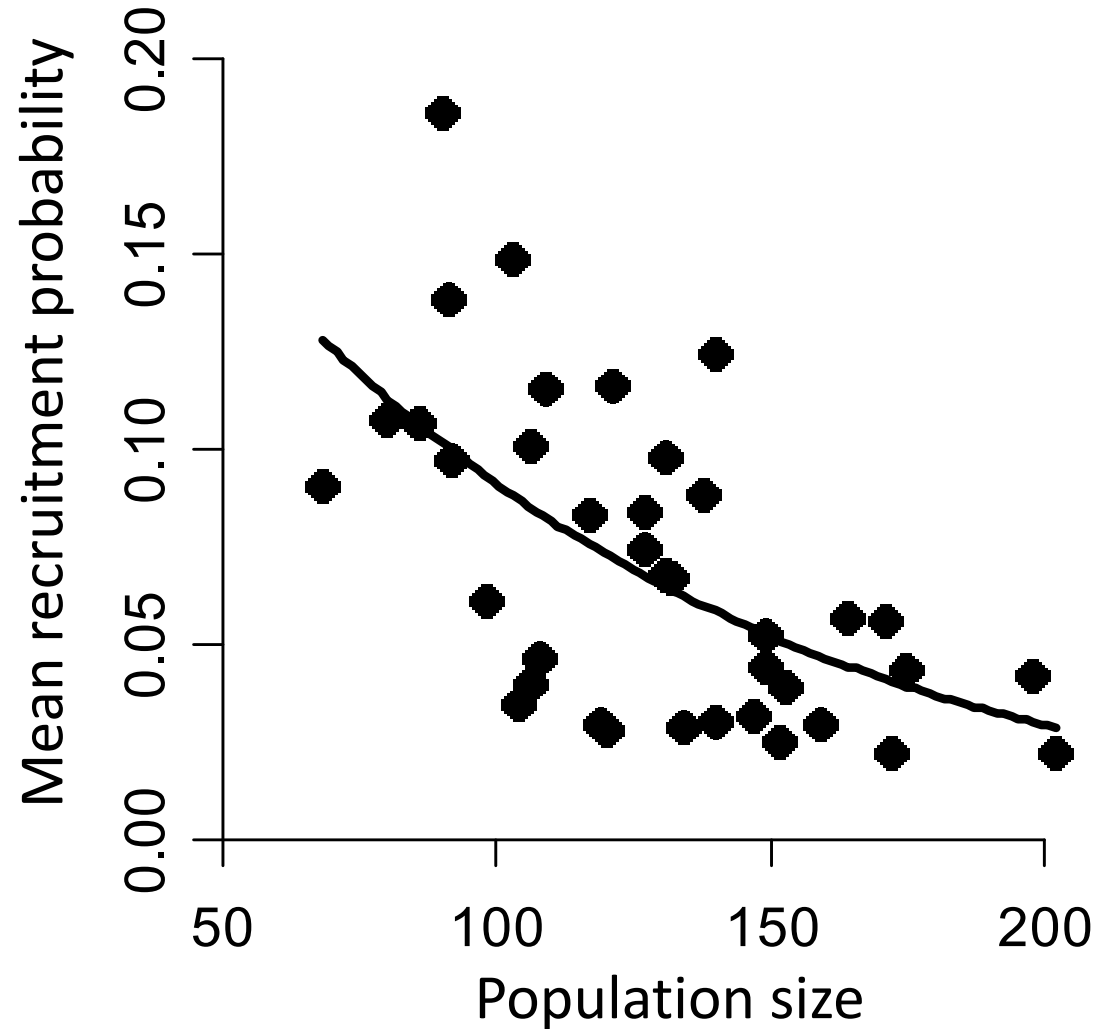
Mismatches thus leads at the population level to a lower mean number of offspring produced

Population consequences of mismatches



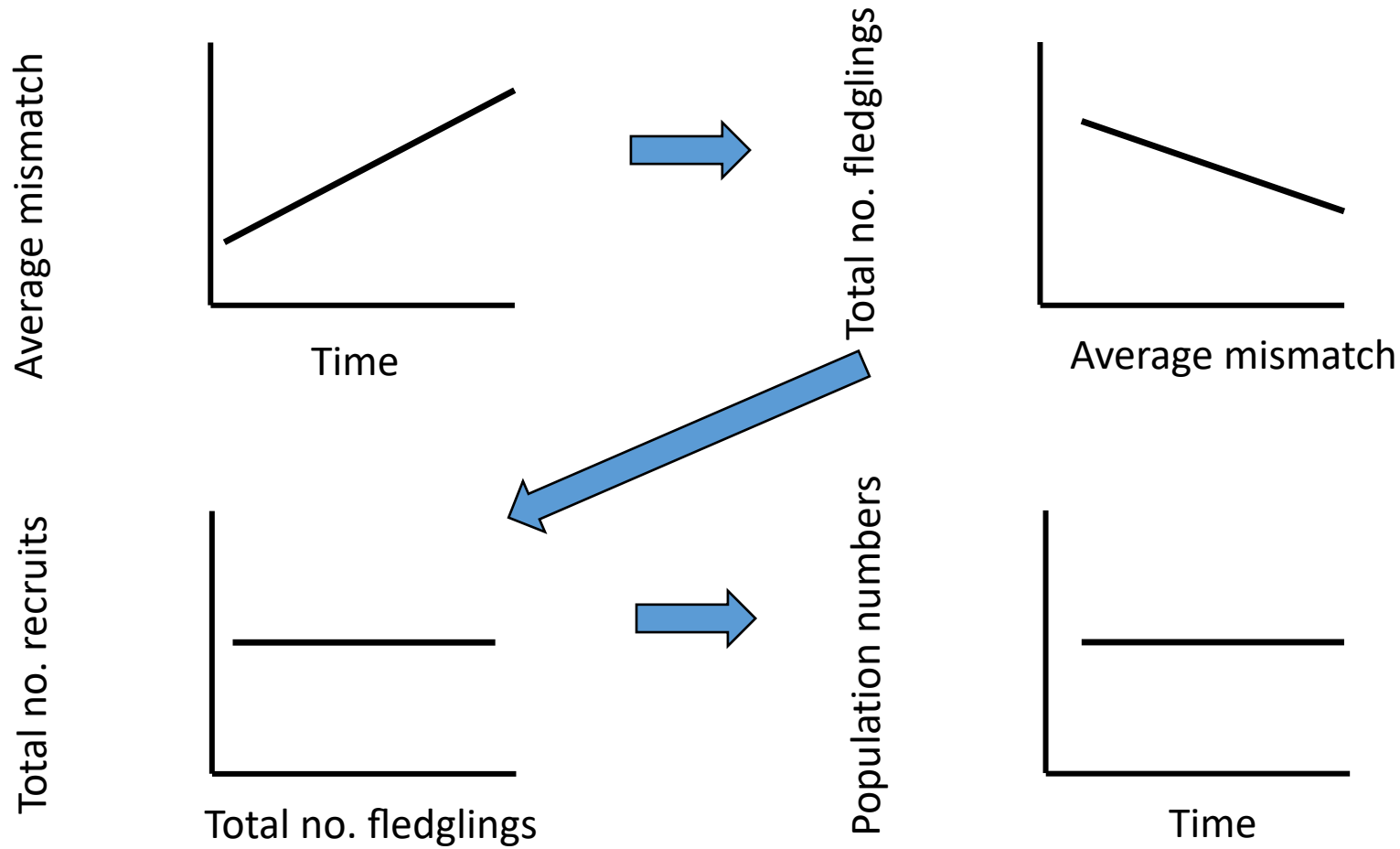
But this reduced number of offspring produced does not lead to lower population growth rates and lower population numbers

Population consequences of mismatches



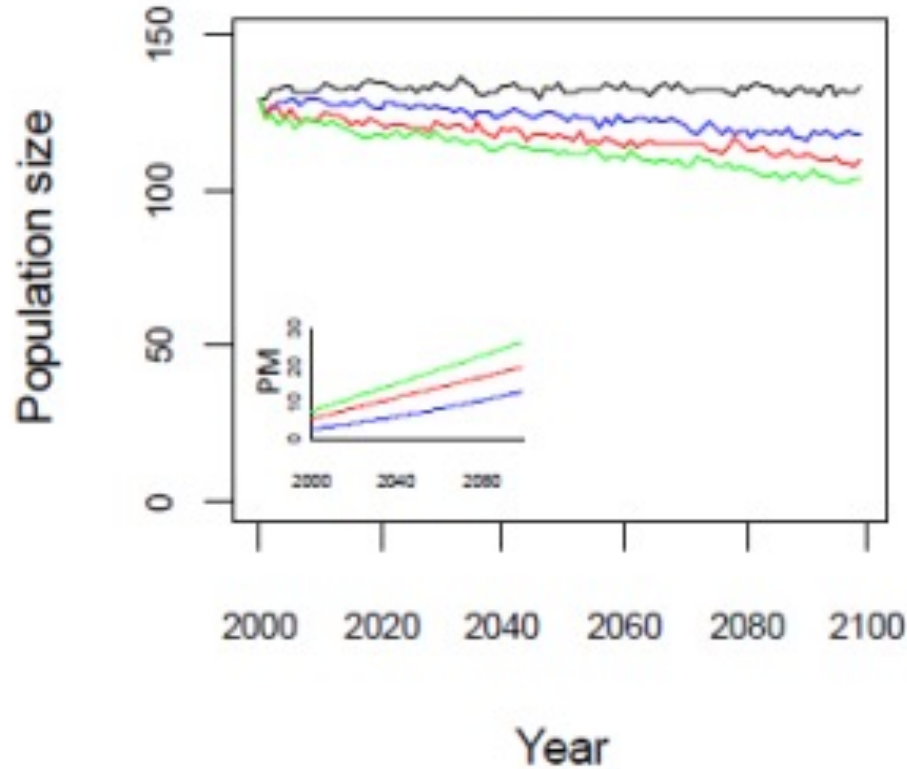
This is because of density dependent recruitment rates

Population consequences of mismatches

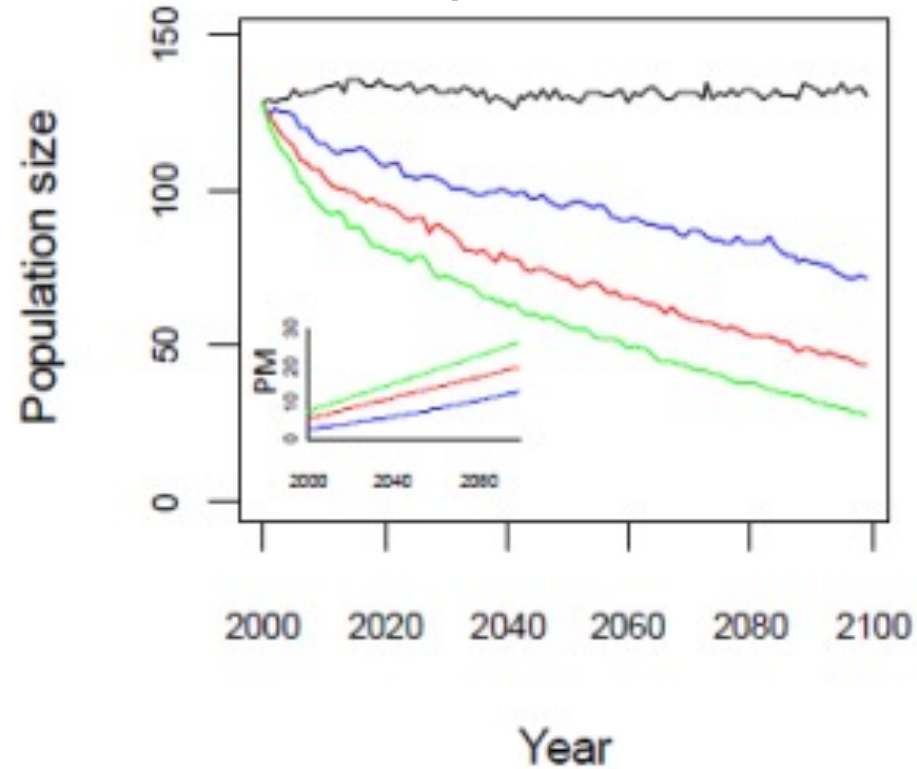


Population consequences of mismatches

With density dependence



Without density dependence

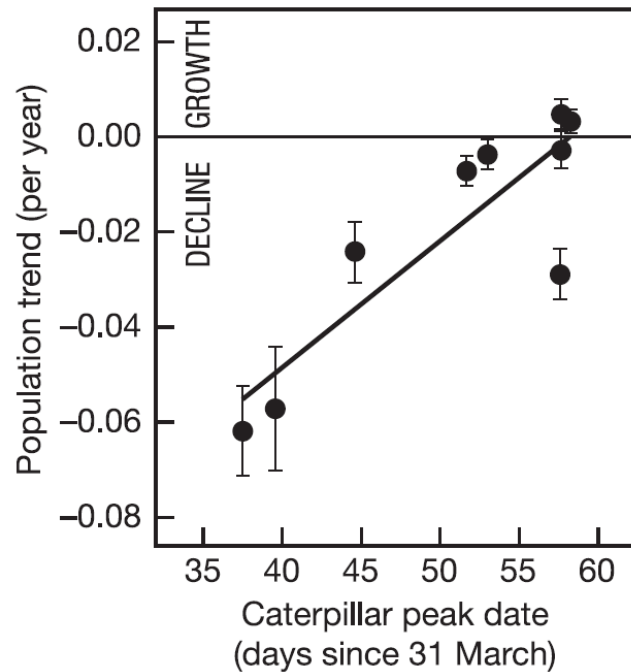


No change / Mild change / Medium change / Fast change

Pied flycatcher populations decline the most in early forests



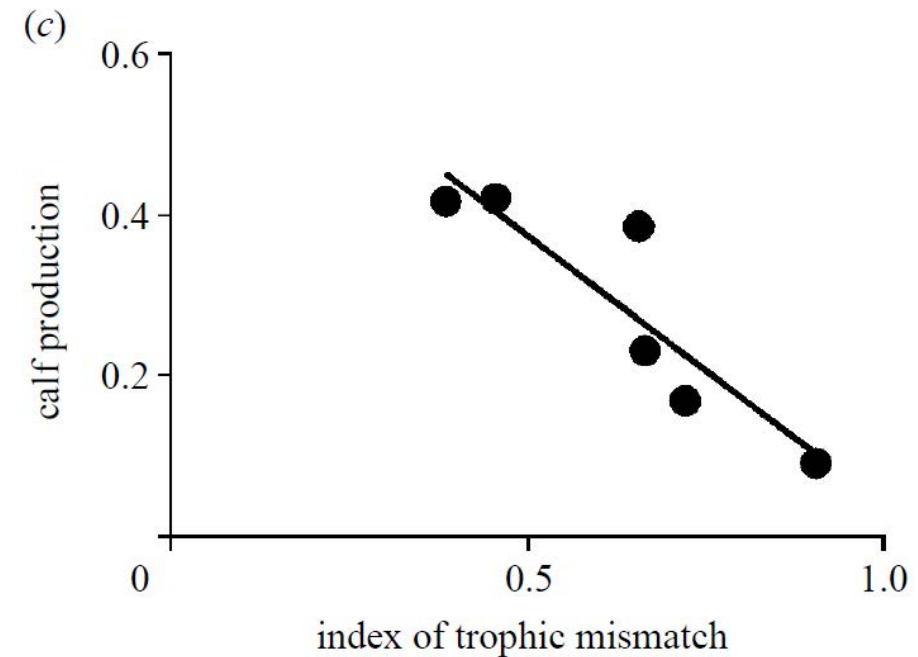
Both et al.
(2006)
Nature



Caribou's calf production declines with phenological mismatch



Post &
Forchhammer
(2008) Phil
Trans B



If populations do not adapt fast enough to climate change, will they decline?

Individual mismatches leads to reduced number of offspring produced which is a major component of fitness

Population mismatches lead to (slightly) lower mean number of offspring produced

Due to density dependent processes, this reduced number of offspring produced does not lead to lower population growth rates and lower population numbers

Overall conclusions: *global climate change leads to ecological relationship problems*

Climate change will lead to unequal shifts in phenology between species within a food chain

This will lead to selection on phenology but the rate of micro-evolution is often low, too low to keep up with climate change

Ecological processes such as density dependence may 'rescue' populations, within limits

Acknowledgements

All the people that contributed to the data collection over the past 68 years &

- Melanie Lindner
- Phillip Gienapp
- Irene Verhagen
- Jip Ramakers
- Veronika Laine
- Tom Reed
- Stephanie Jenouvrier



European Research Council
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Phenological Shifts:

Interrupting the Rhythm of Nature



#Frontiers2022



<https://www.unep.org/resources/frontiers-2022-noise-blazes-and-mismatches>