# Adapting to a warming world: micro-evolution of seasonal timing of winter moth egg hatching

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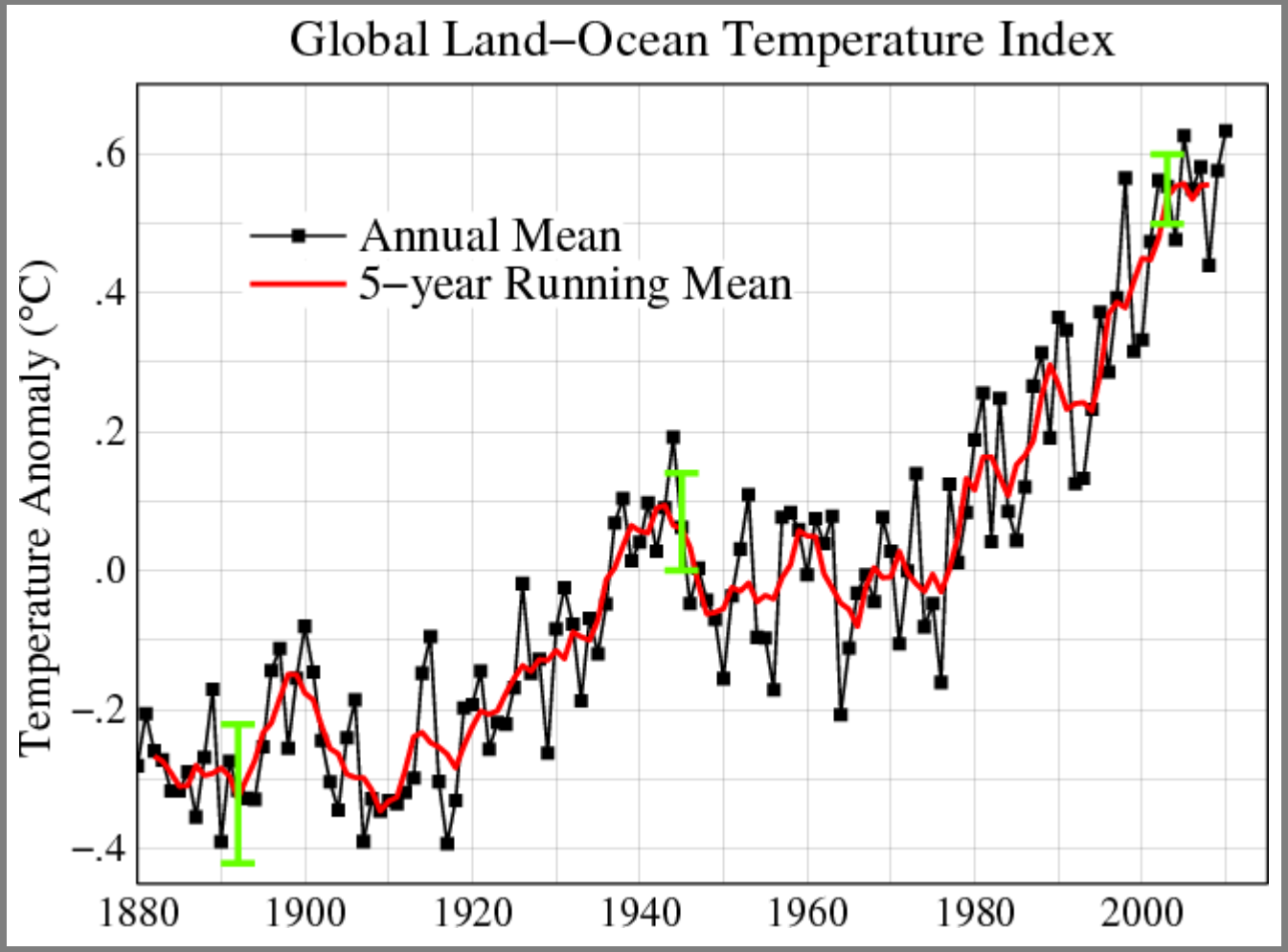
# Climate change




Global mean land-ocean temperature change from 1880-2010, relative to the 1951-1980 mean

Source: NASA

# Ecological consequences of climate change

One of the clear effects is a shift in phenology

Parmesan & Yohe, Nature 2003

*Phenology* is the study of the times of recurring natural phenomena

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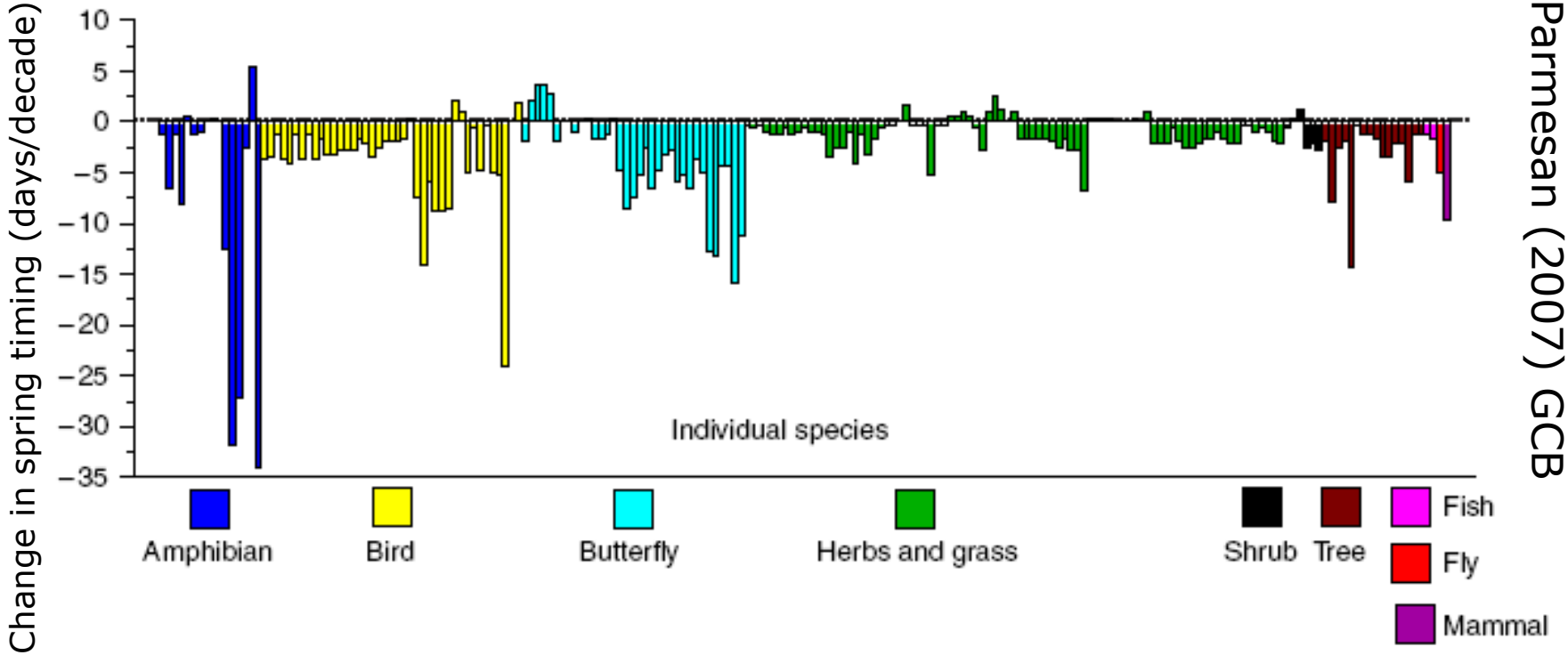
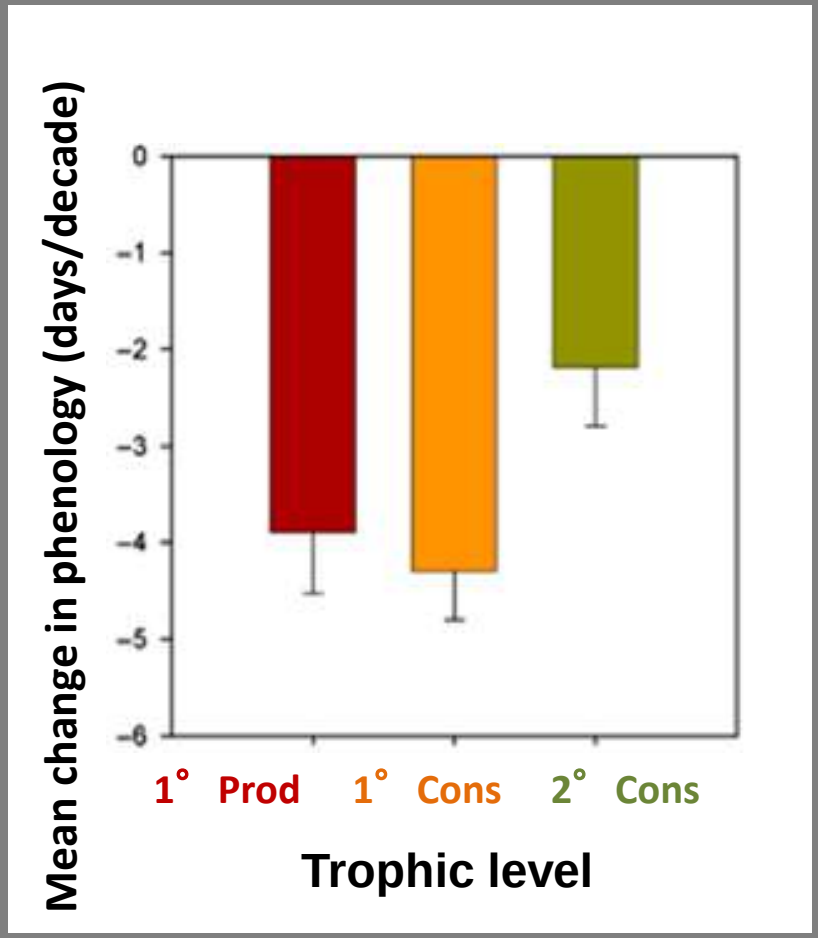
# Differential shifts in phenology



# Differential shifts in phenology




Thackeray et al. (2010) GCB

# Winter moth system

Oak

Winter Moth

(Visser & Holleman Proc R Soc 2001; van Asch et al. GCB 2007)



November / December

April

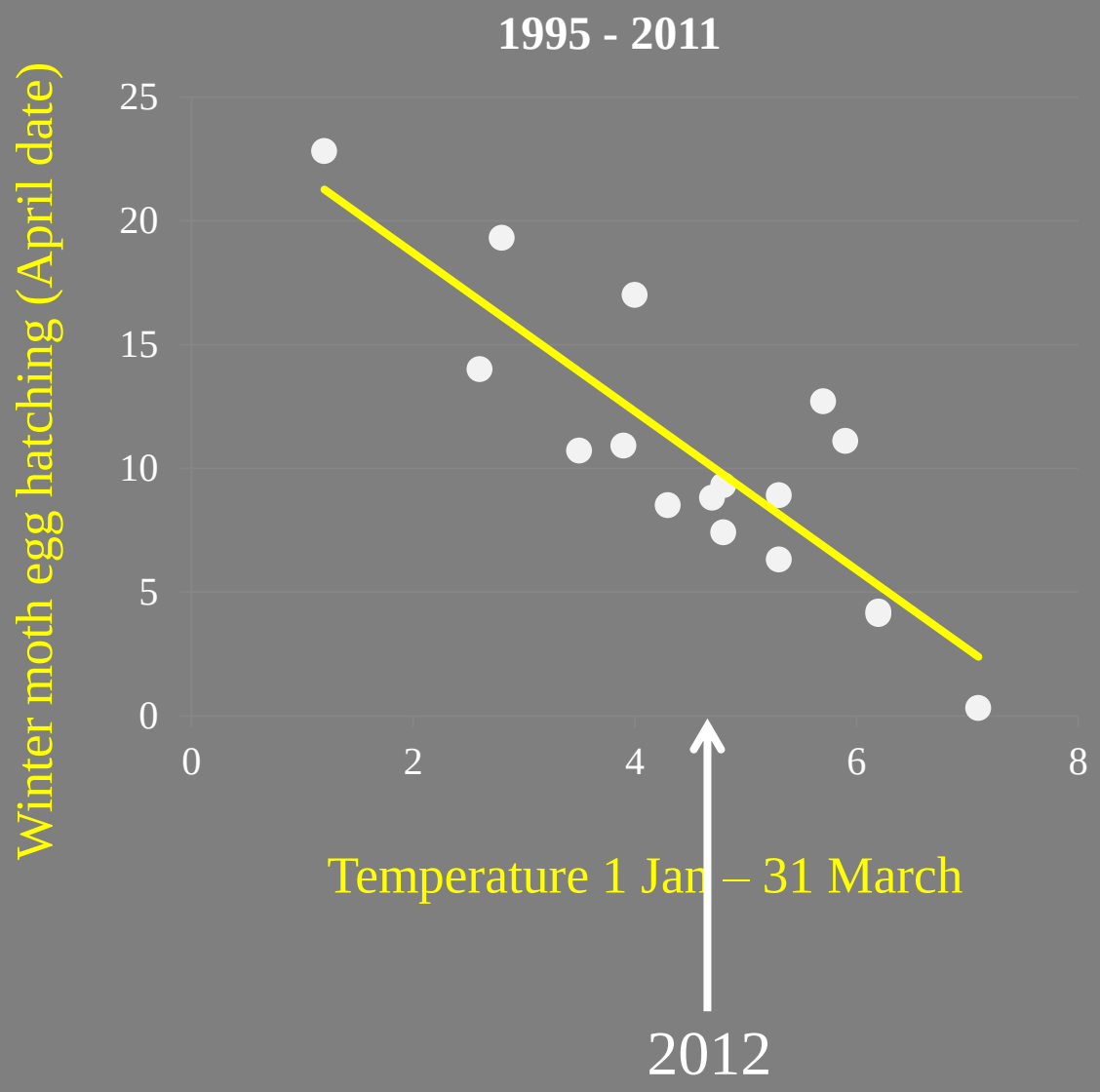
Winter moth (*Operophtera brumata*) caterpillars feeding on oak (*Quercus robur*) leaves

# Phenotypic plasticity

Winter moth egg hatching (April date)

Temperature 1 Jan – 31 March

# Phenotypic plasticity



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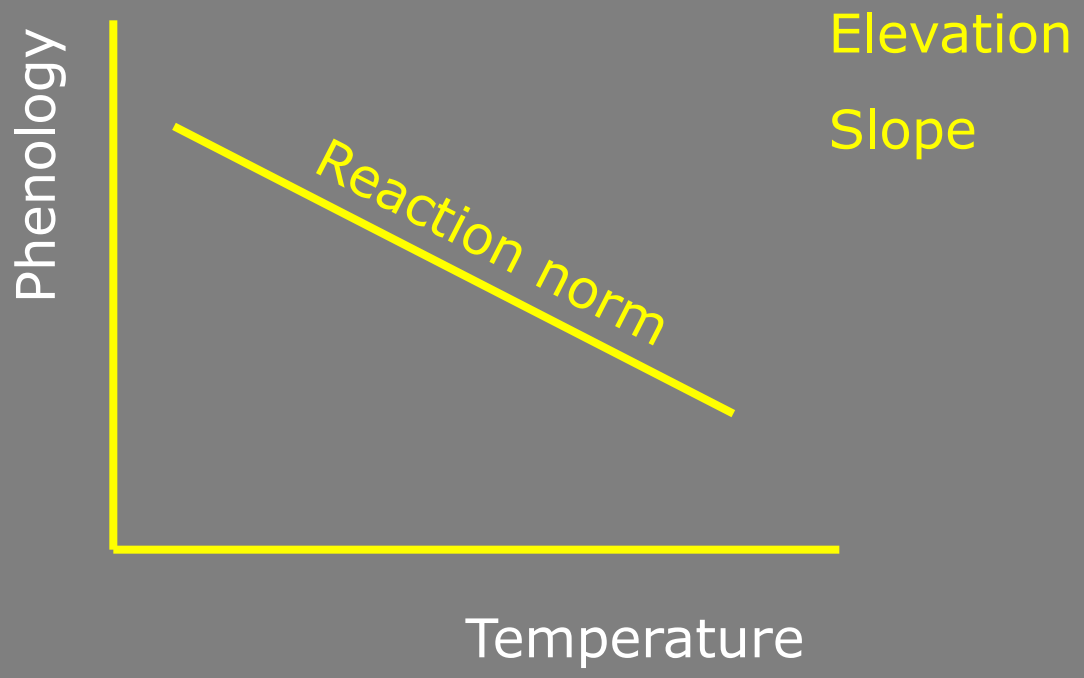

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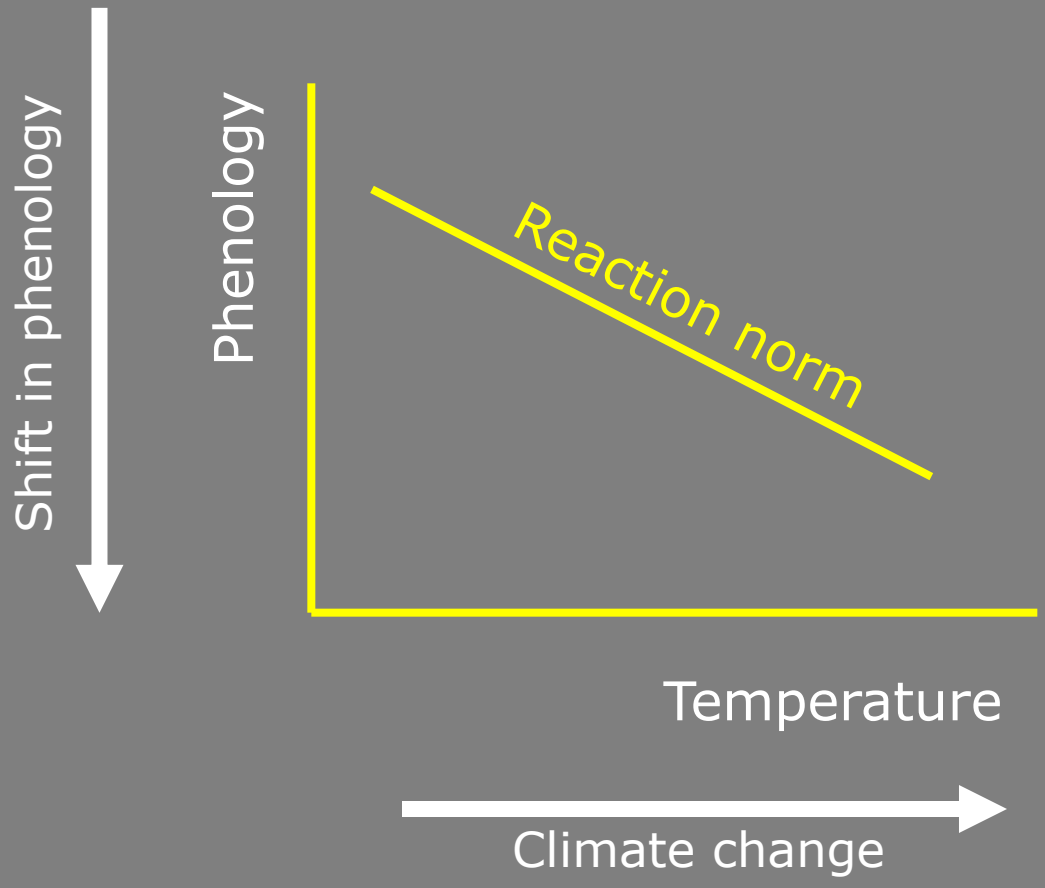
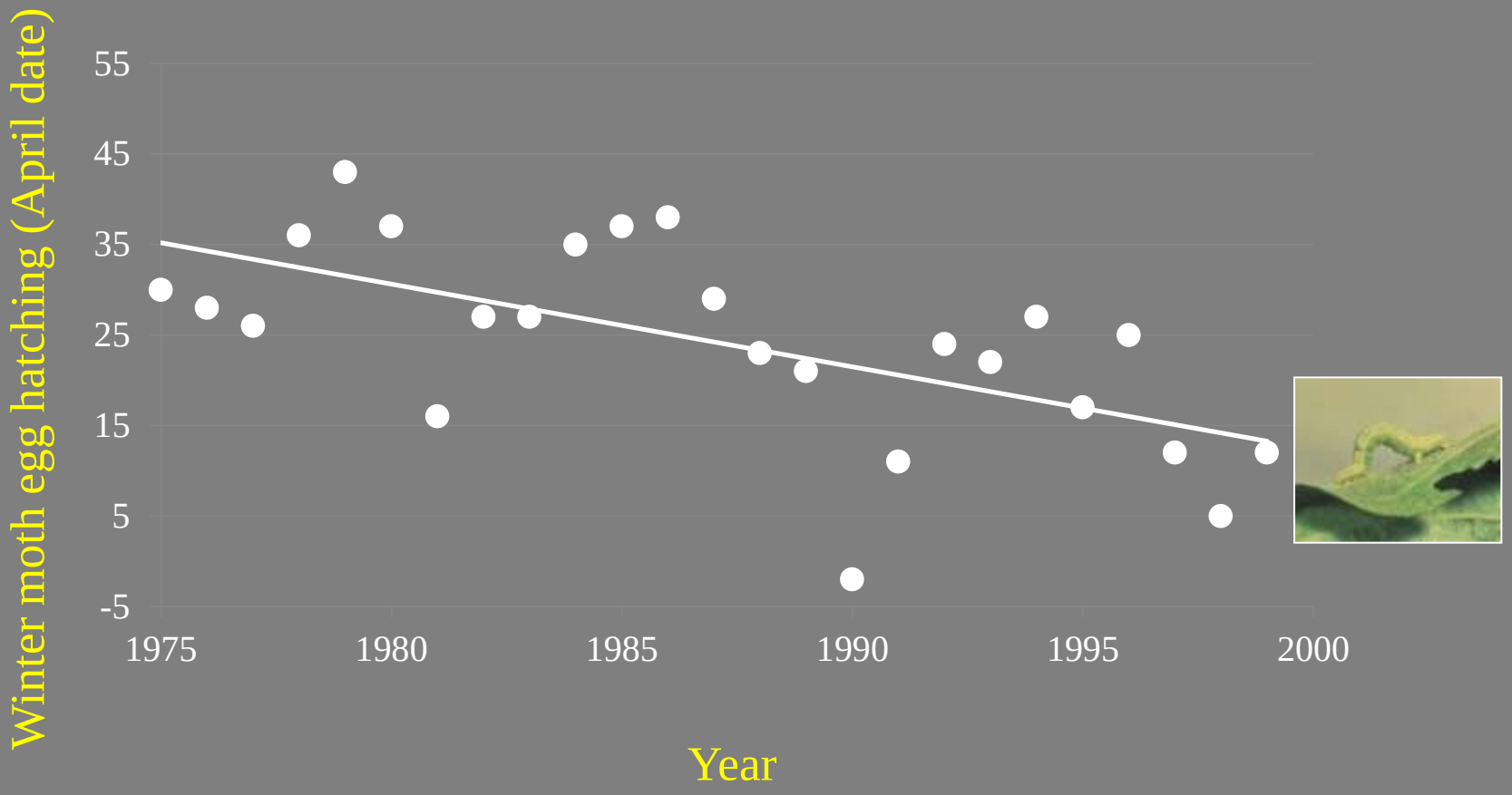


# Mismatched egg hatching



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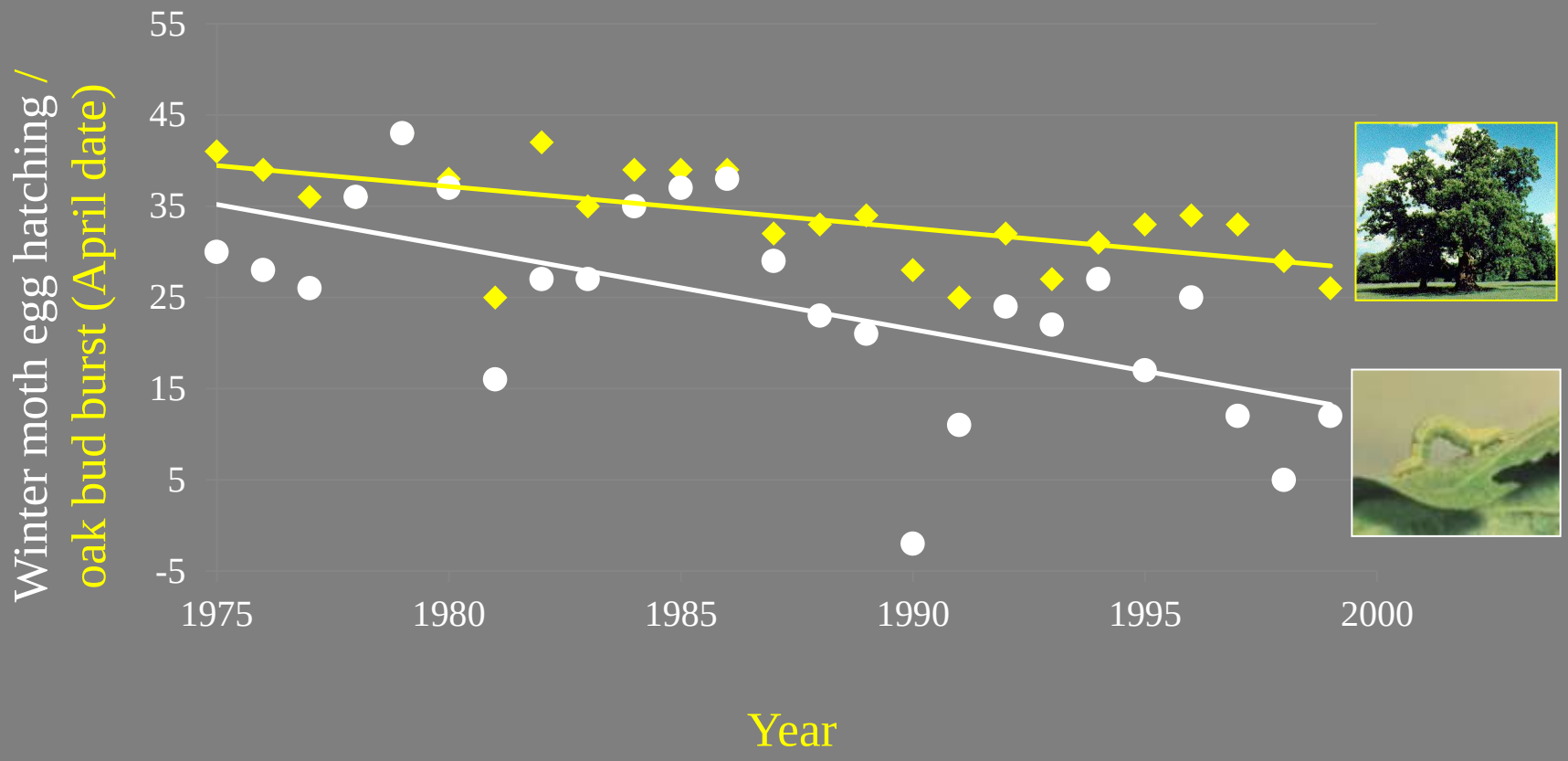
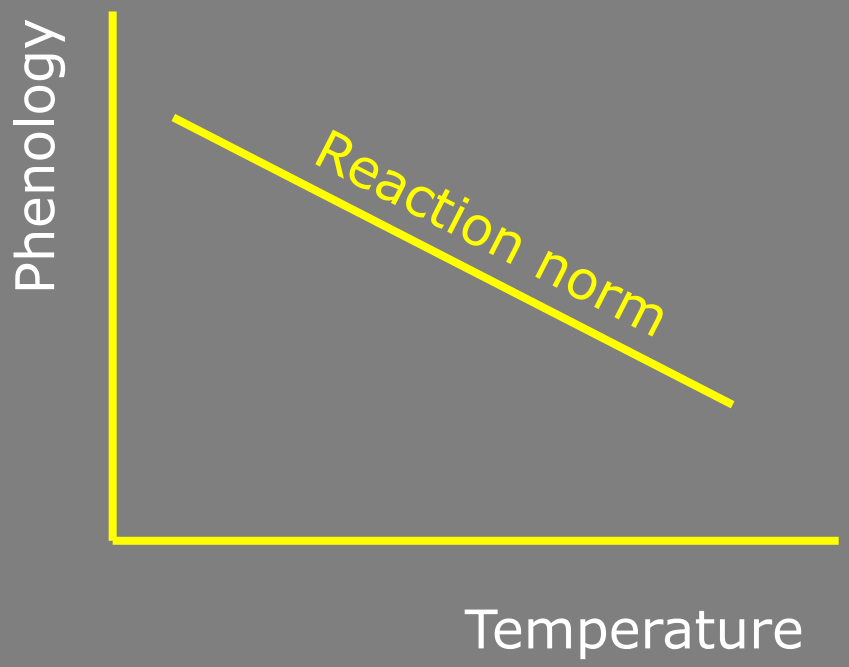


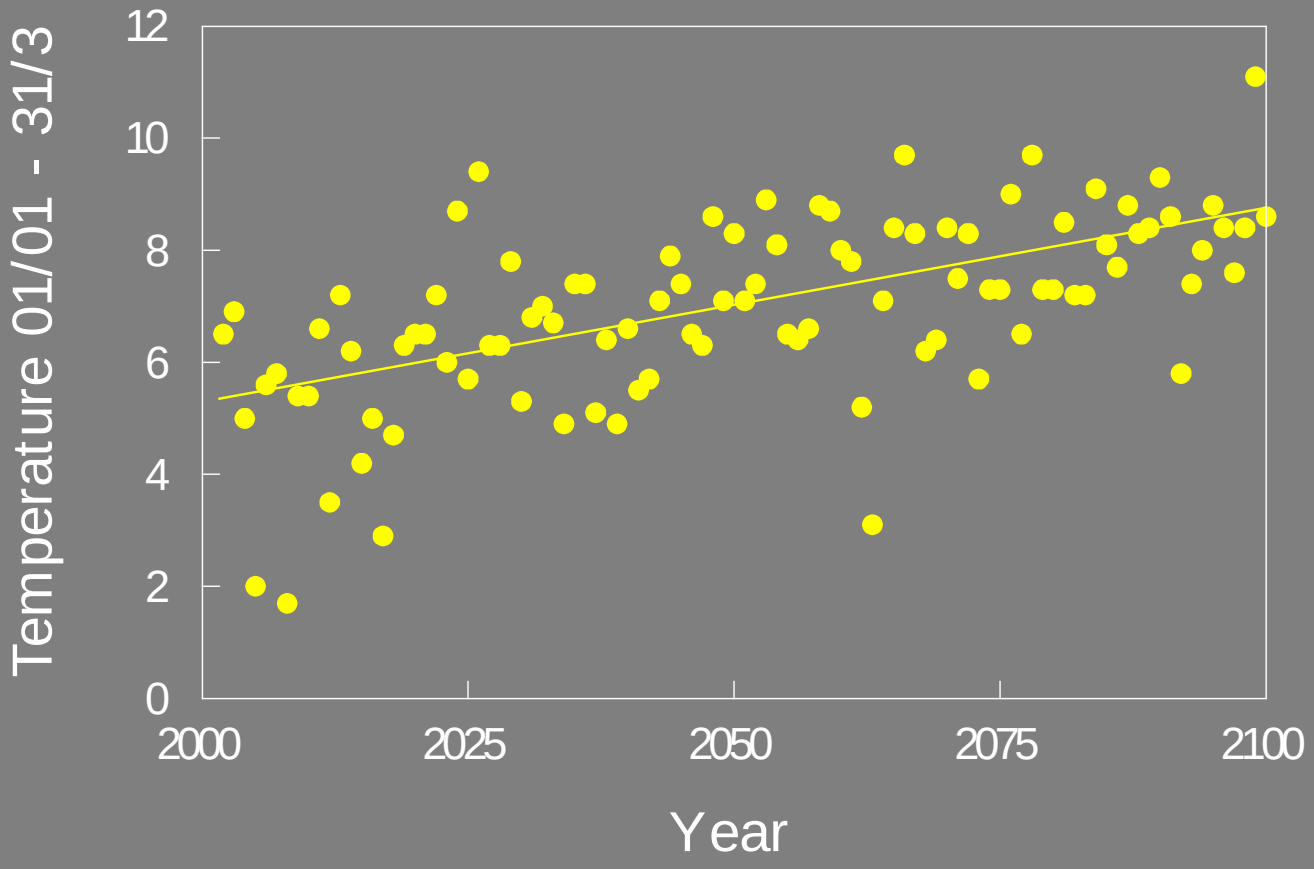
# Phenotypic plasticity no longer adaptive



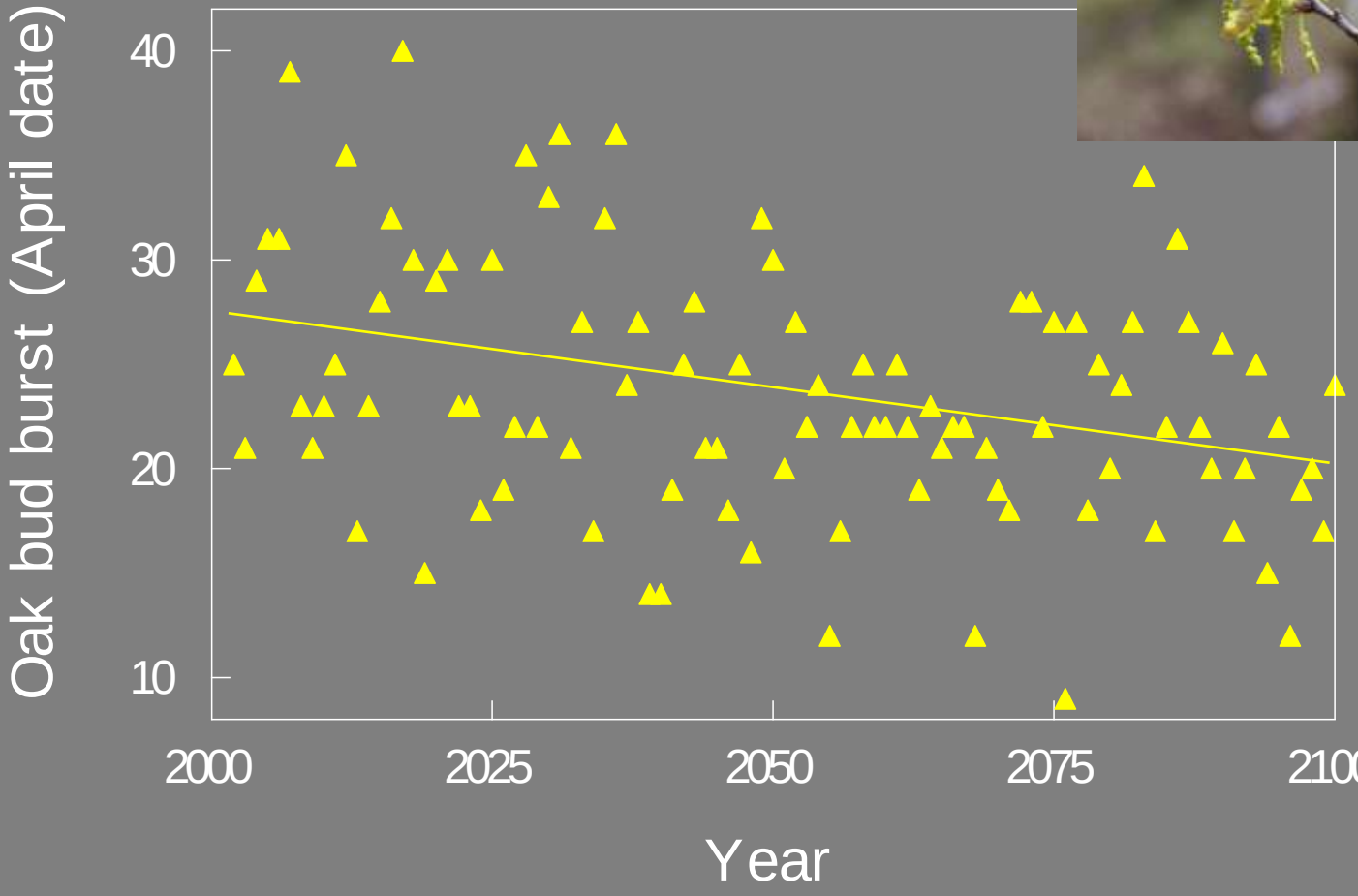

Genetic change in the reaction norm is needed

# Predicted changes in spring temperature

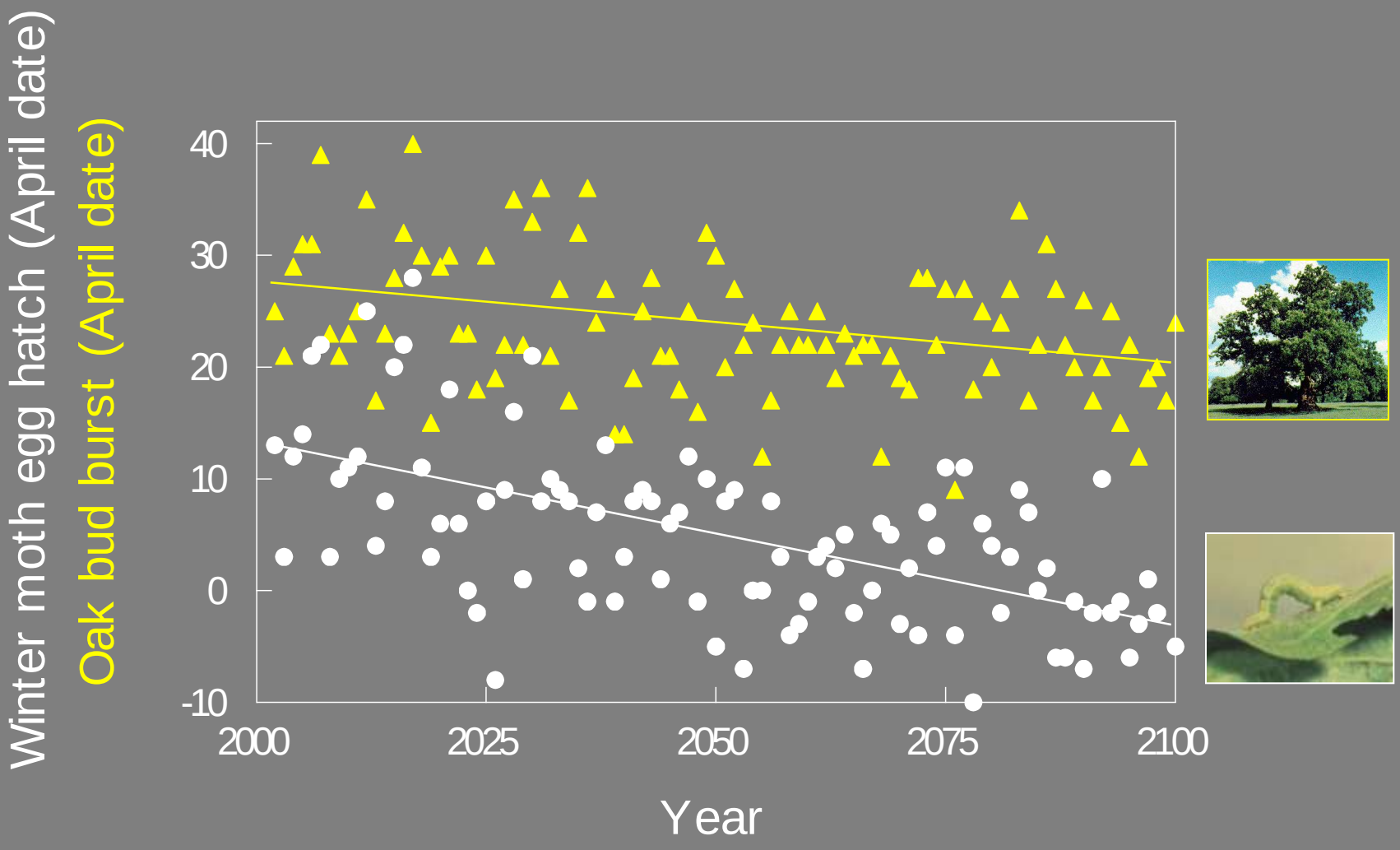
(using the IPCC-SRES-B2 ECHAM 4 climate model)



# Predicted changes in oak budburst



# Predicted changes in Oak bud burst and in hatching date Winter Moth (without adaptation)

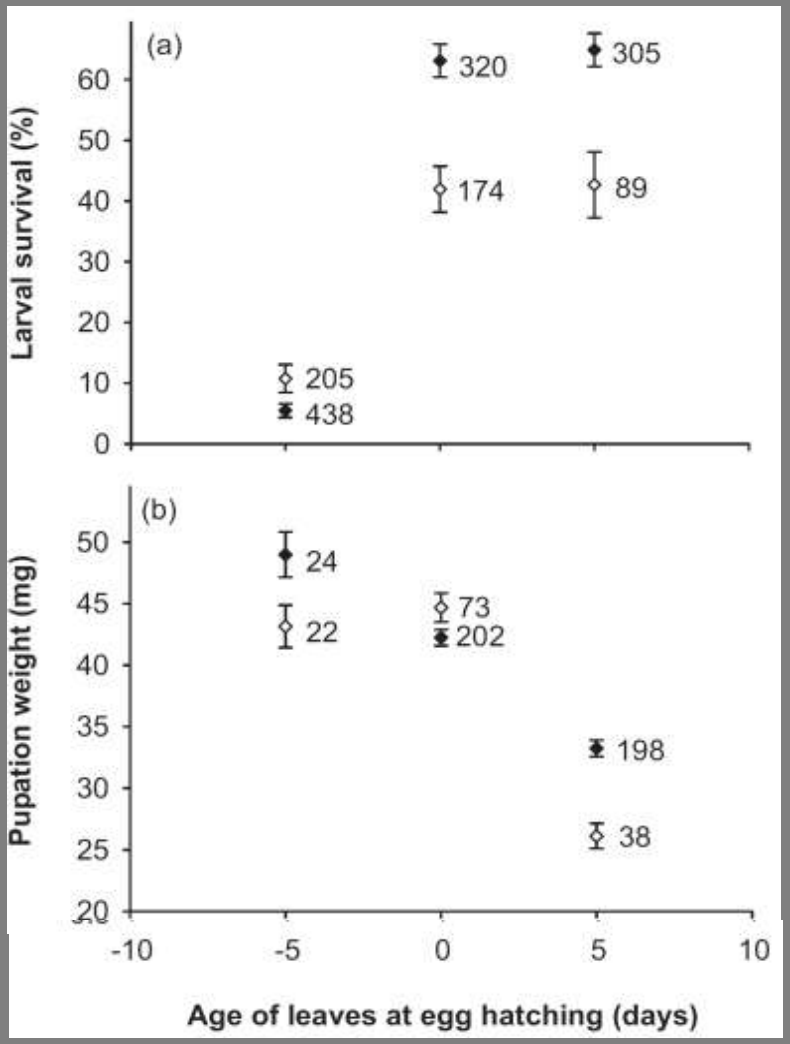


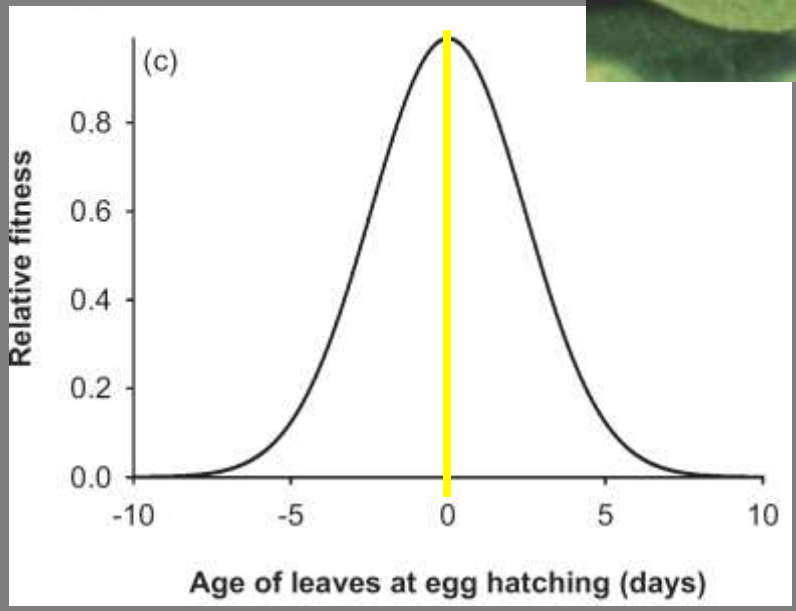
# Predicted adaptation in egg hatching date

What is needed is micro-evolution of the reaction norm:

- Selection for synchrony
- Heritability of reaction norm
- Response to this selection

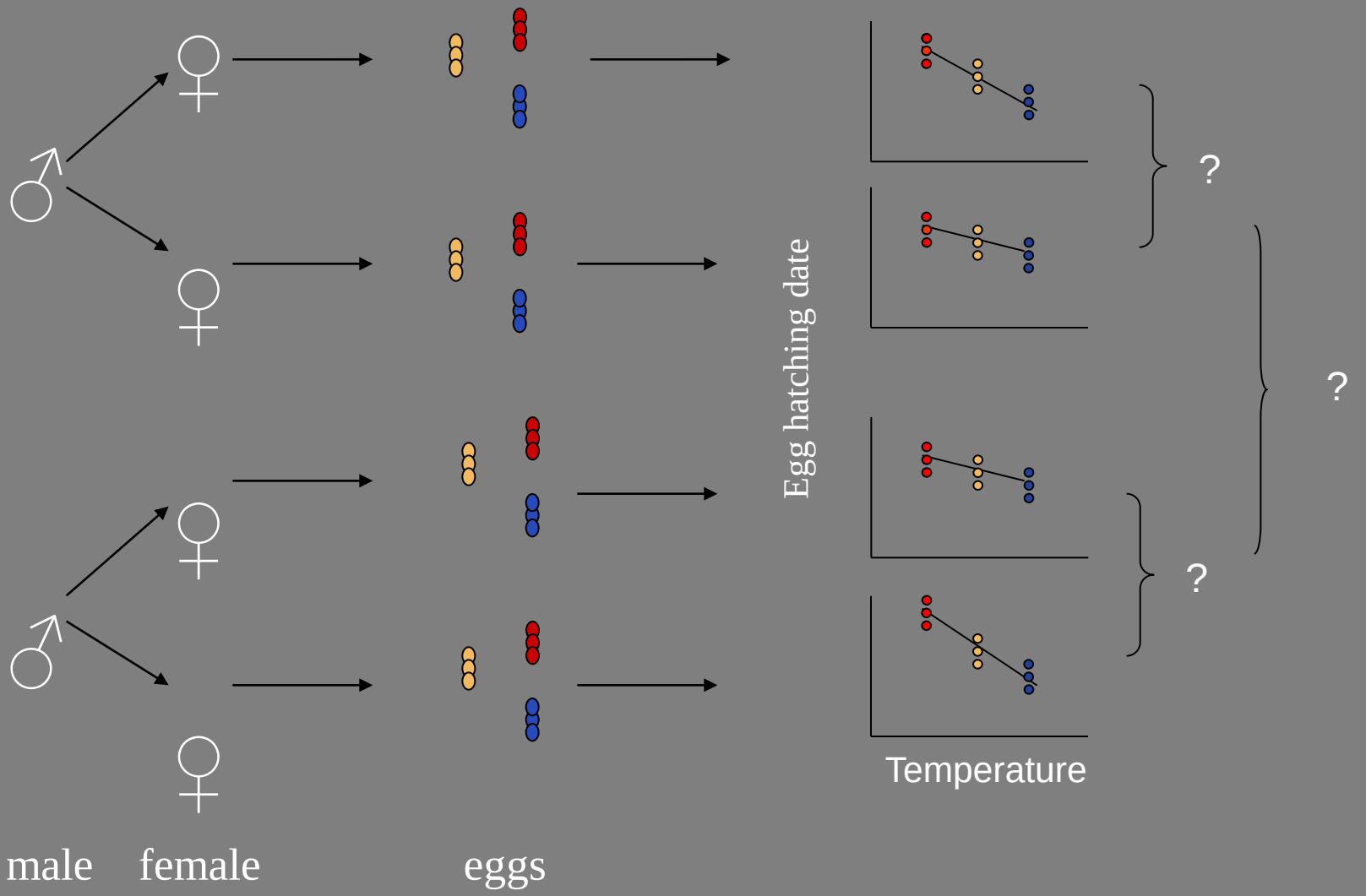
# Selection for synchrony



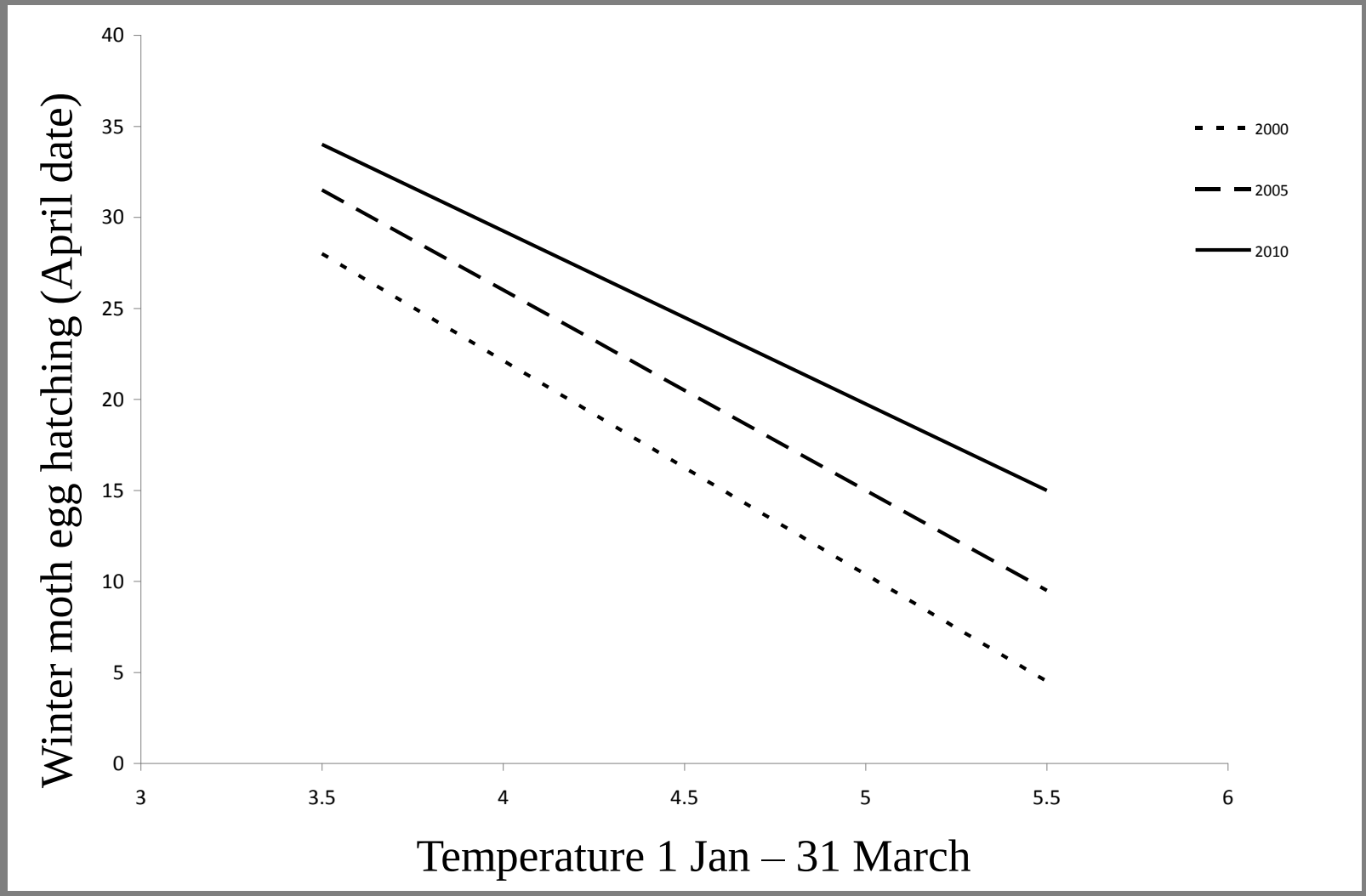




Van Asch et al. GCB 2007

# Genetic variation in temperature sensitivity



# Response to selection on temperature sensitivity

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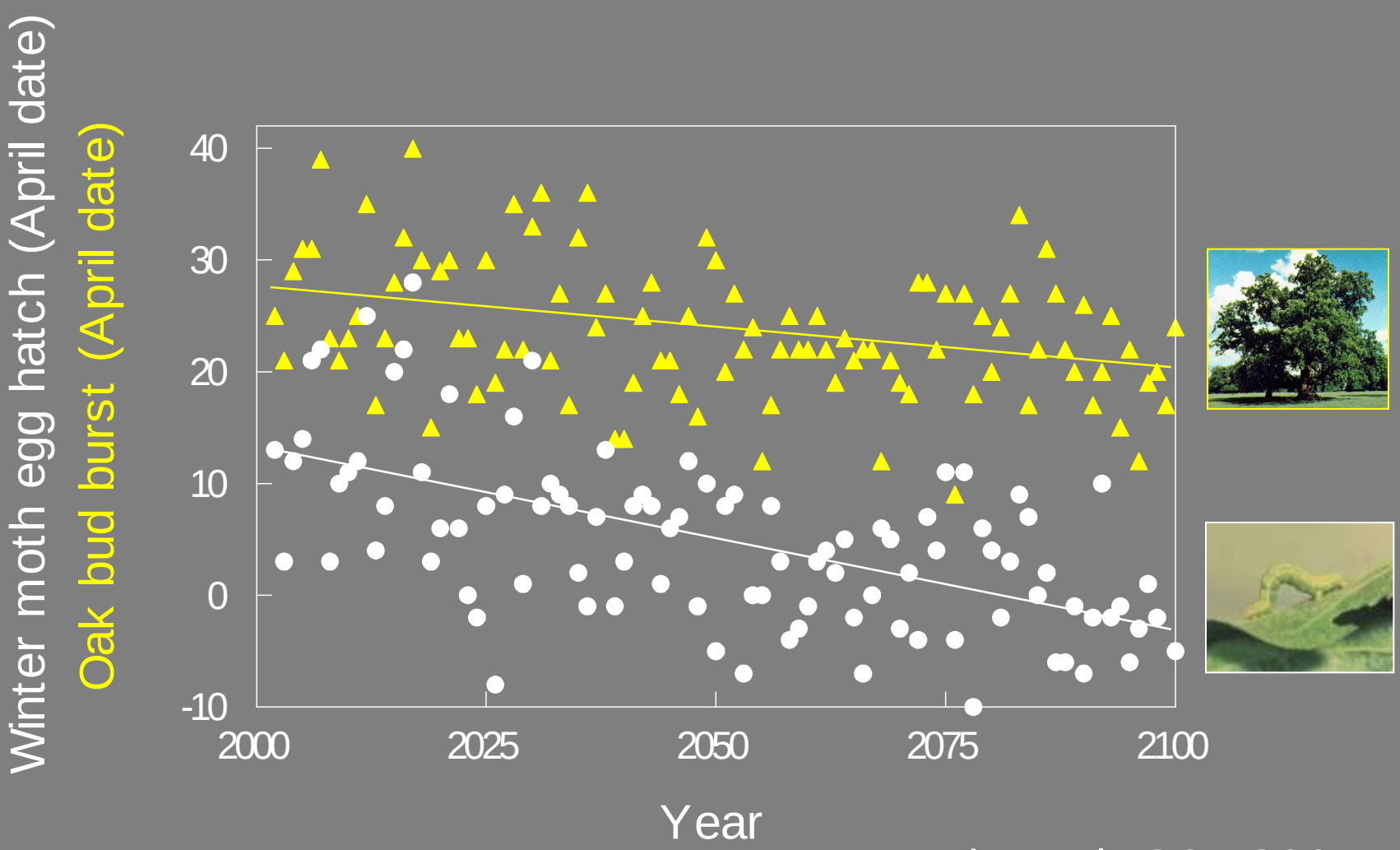


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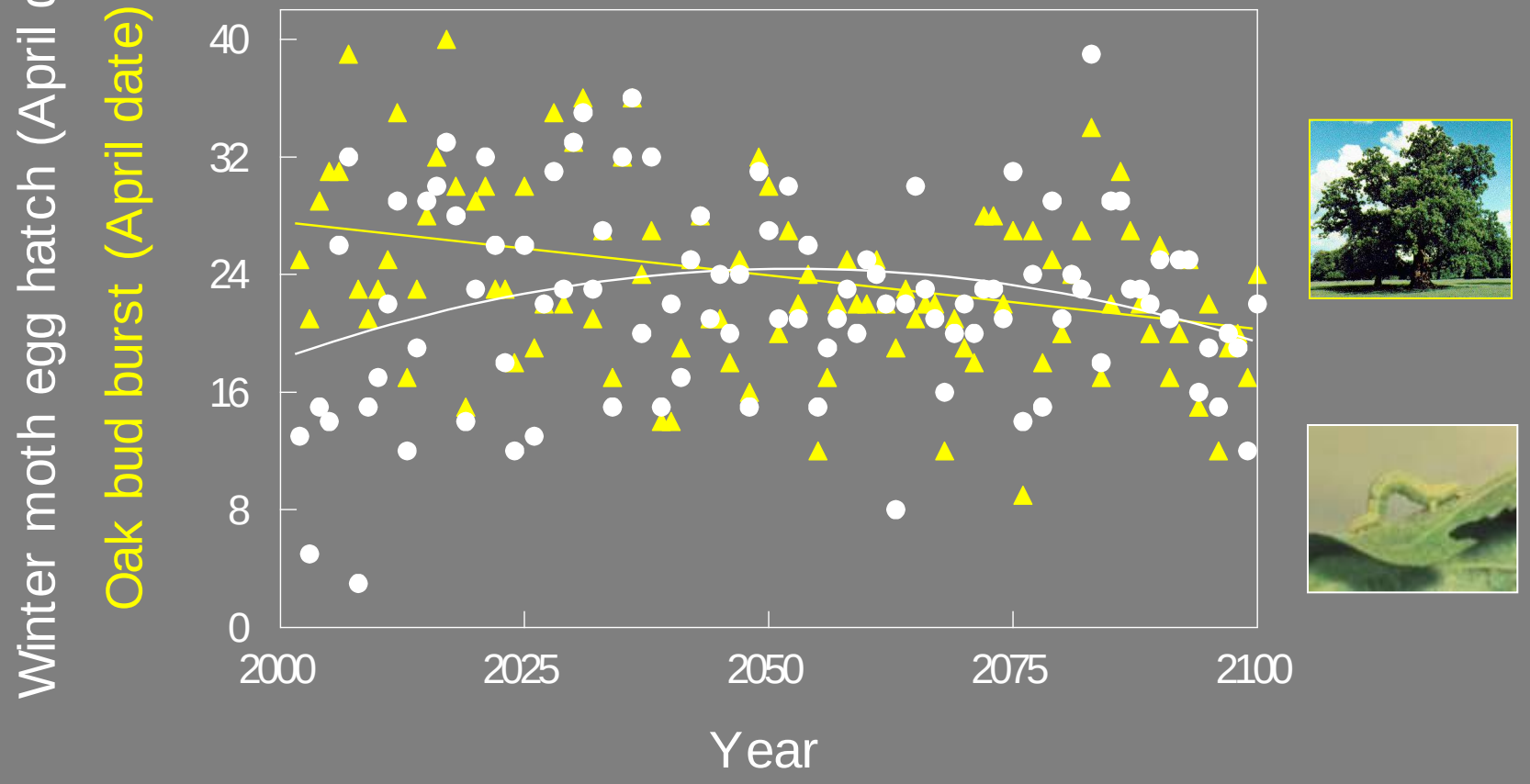
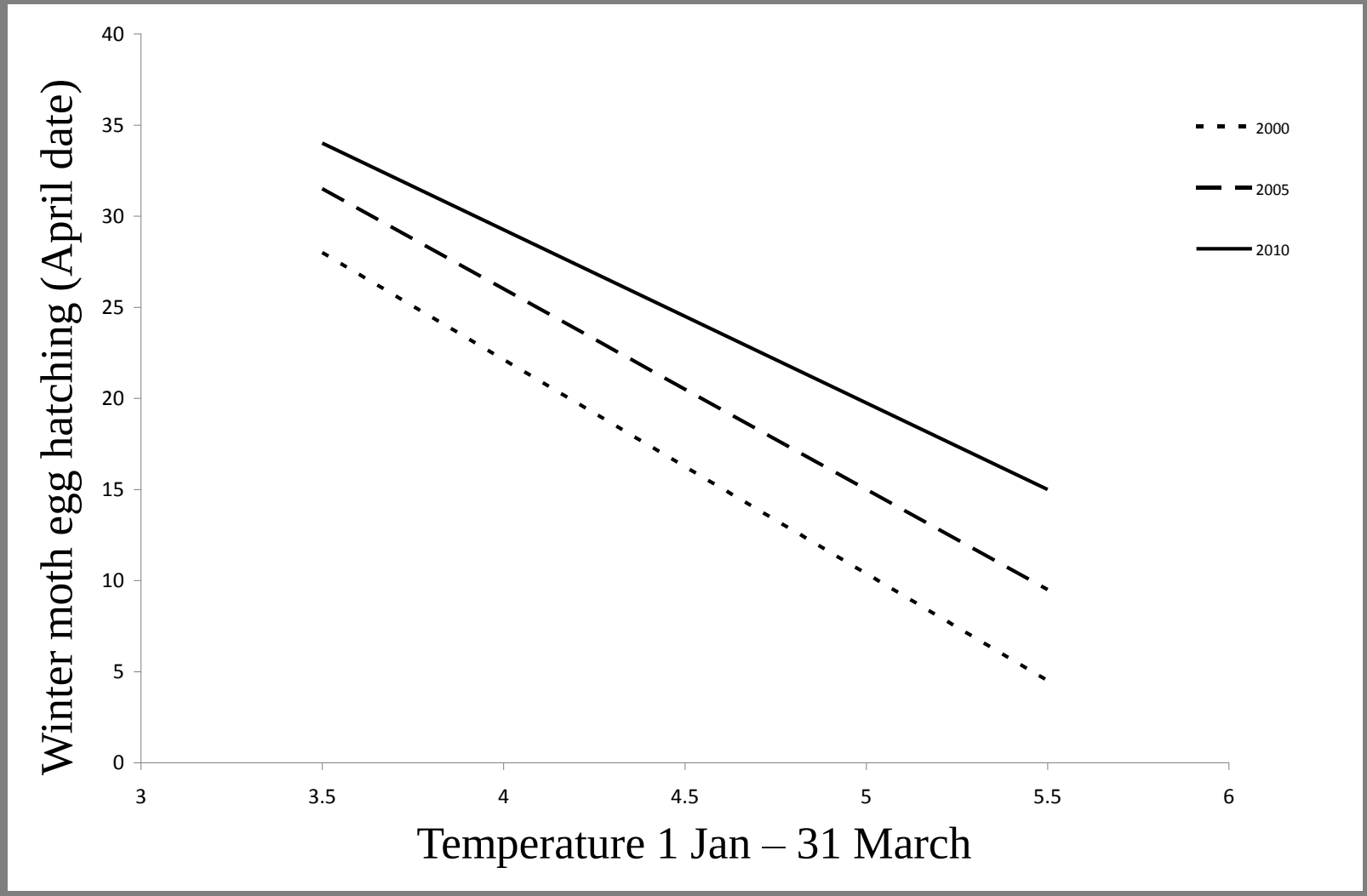







Van Asch et al. GCB 2007

# Testing the predicted response to selection on temperature sensitivity

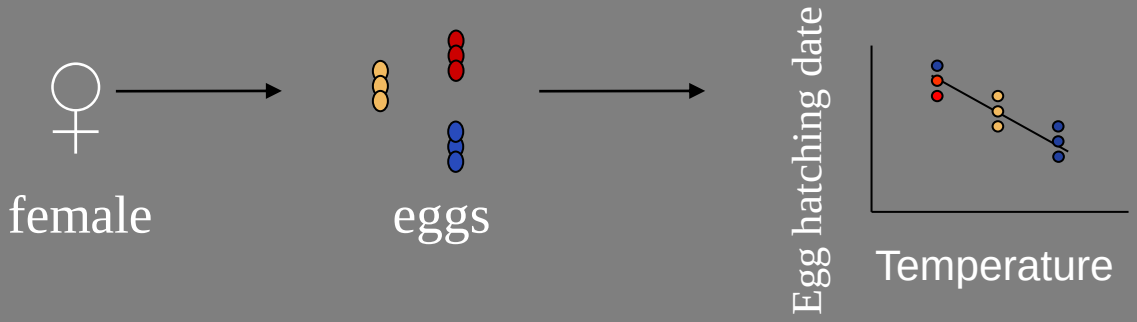


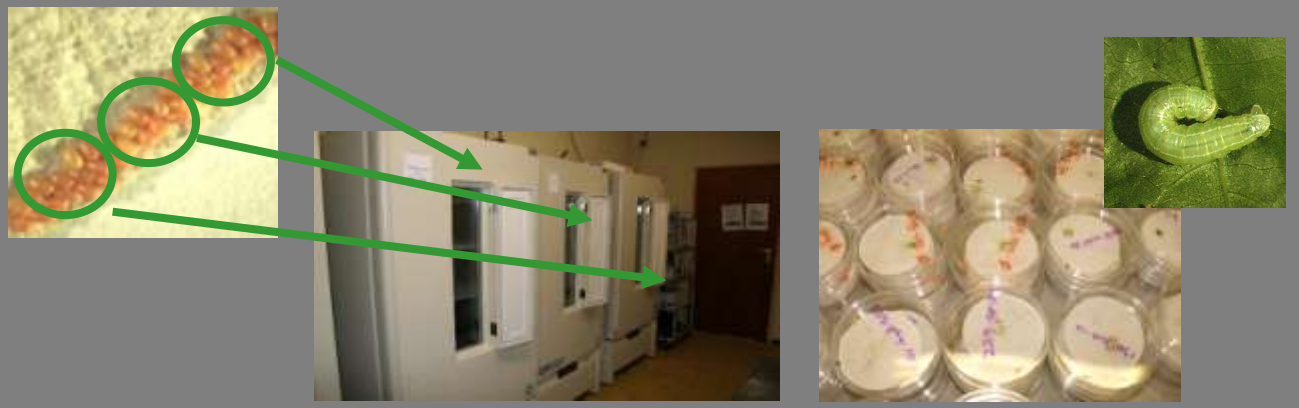
# Response to selection on temperature sensitivity



# Response to selection on temperature sensitivity

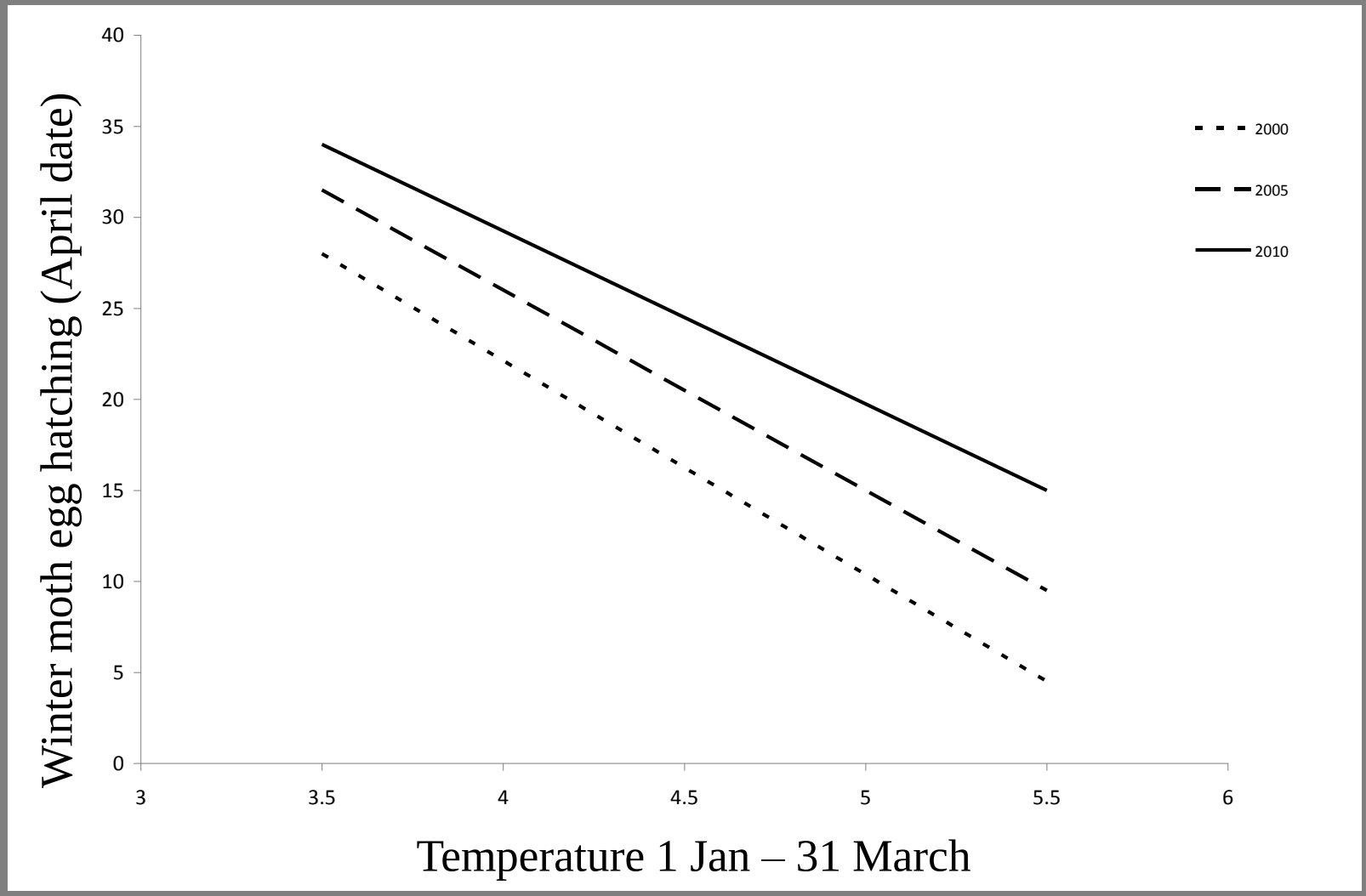
## Experiment in climate cabinets



Experiment in 2000, repeated in 2005 and 2010

# Response to selection on temperature sensitivity



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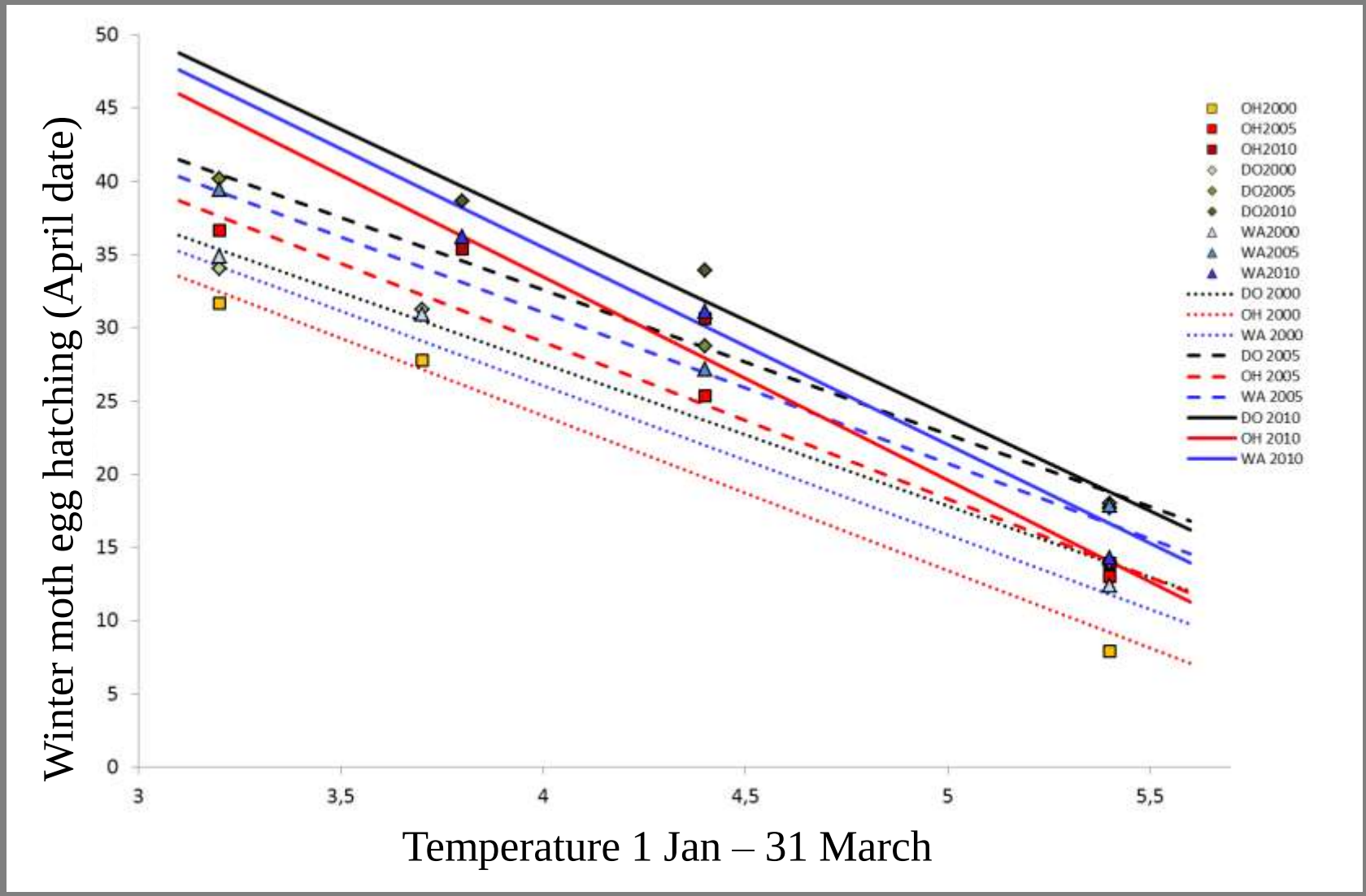

# Response to selection on temperature sensitivity

## Field data


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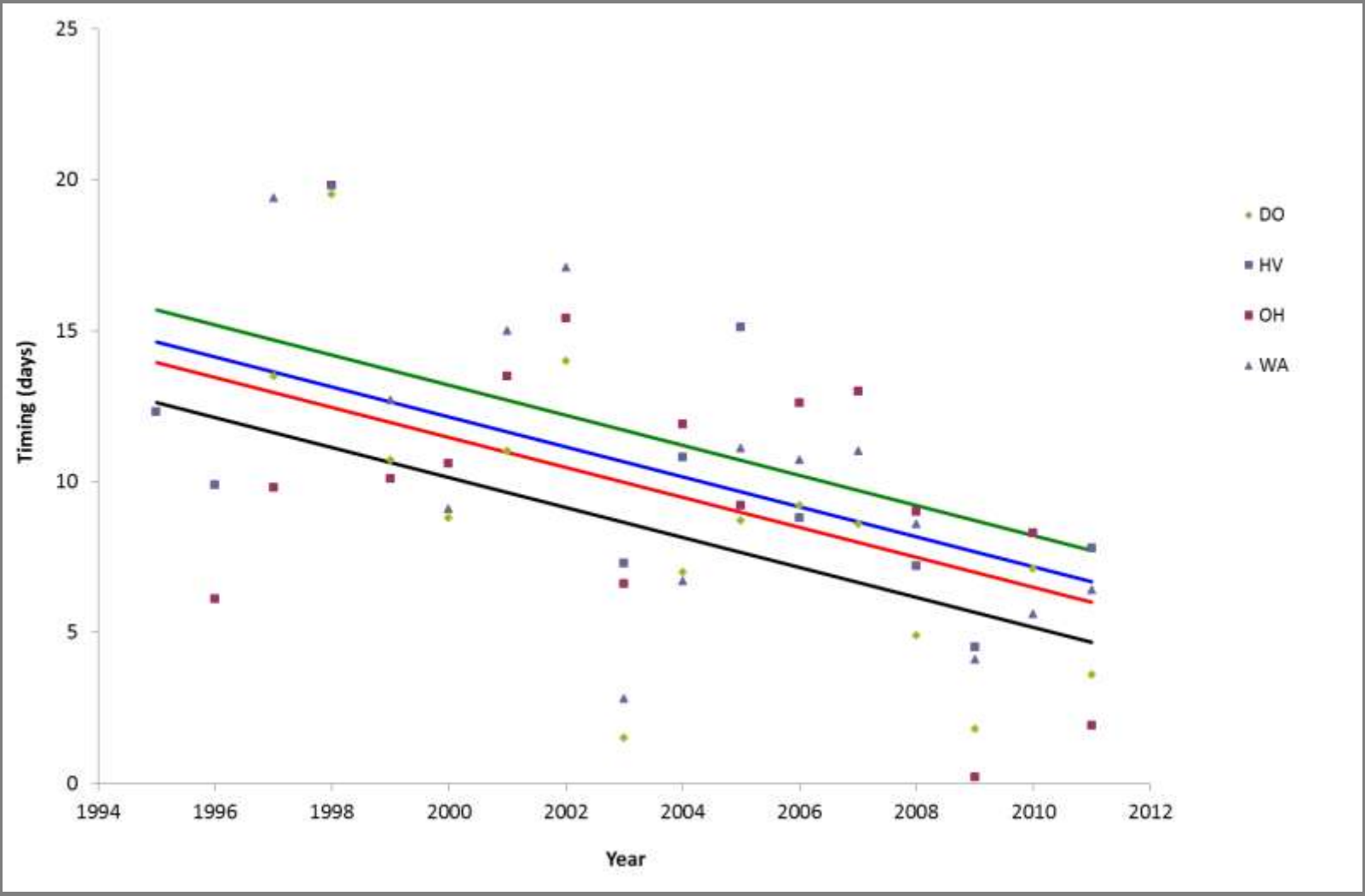

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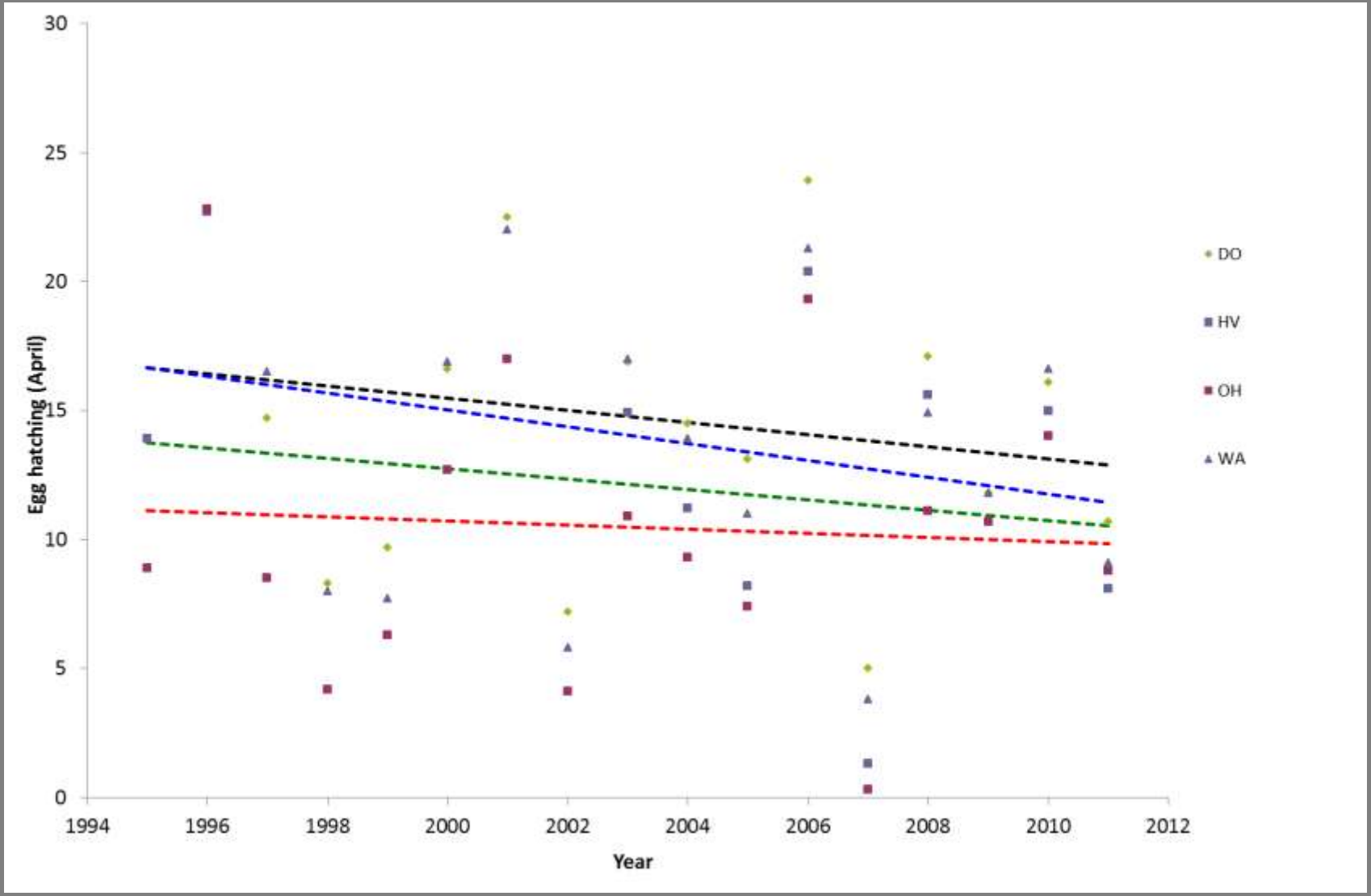

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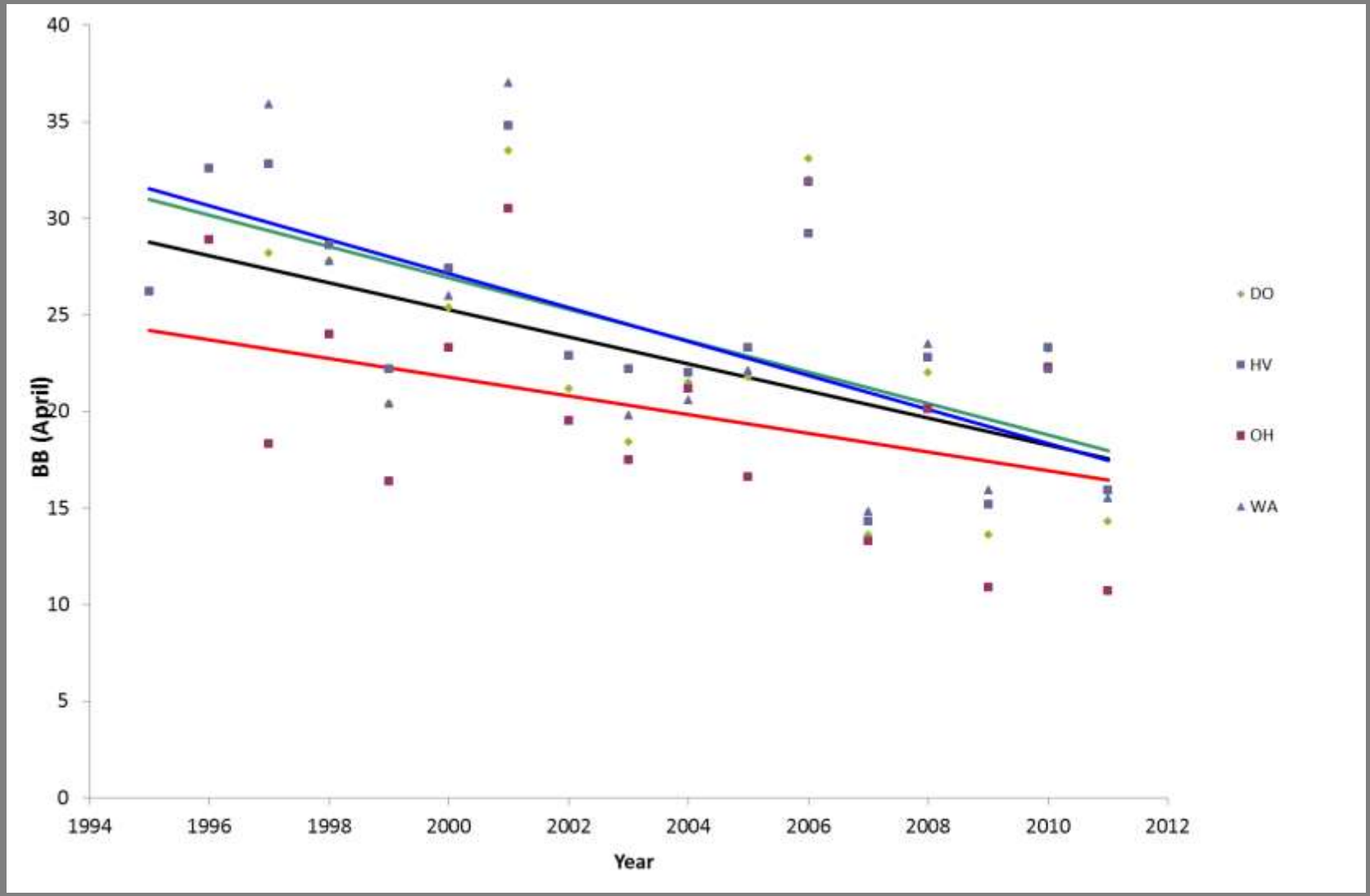

# Conclusions winter moth system

In Winter Moths, there is heritable variation in temperature sensitivity

Winter Moths which are *least* sensitive to temperature have the highest fitness

The rate of adaptation is predicted to be quite high (0.2–0.4 days a year) which seems high enough to keep up with moderate climate change

Experiments confirm the rate of adaptation of the reaction norm

First appearance of the Orange tip (*Anthocharis cardamines*) and the flowering date of Garlic mustard (*Alliaria petiolata*)

Return date of the Red admiral (*Vanessa atalanta*) and the flowering date of the Stinging nettle (*Urtica dioica*)

How general are the findings for the winter moth?

Can species adapt to their warming world?