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

Marcel E. Visser, Lucia Salis & Margriet van Asch
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

www.natuurkalender.nl
Differential shifts in phenology

Parmesan (2007) GCB
Differential shifts in phenology

Mean change in phenology (days/decade)

Trophic level

1° Prod  1° Cons  2° Cons

Thackeray et al. (2010) GCB
Winter moth system

(Oak)

(Winter Moth)

(Visser & Holleman Proc R Soc 2001; van Asch et al. GCB 2007)
Winter moth (*Operophtera brumata*) caterpillars feeding on oak (*Quercus robur*) leaves

- 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

Temperature 1 Jan – 31 March

2012

Winter moth egg hatching (April date)
Mismatched egg hatching

Winter moth egg hatching (April date)

Year

Graph showing the trend of mismatched egg hatching from 1975 to 2000.
Mismatched egg hatching

Year

Winter moth egg hatching / oak bud burst (April date)
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

- Year
- Oak bud burst (April date)
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

male    female                  eggs

Temperature

Egg hatching date
Response to selection on temperature sensitivity

Van Asch et al. GCB 2007
Predicted changes in Oak bud burst and in hatching date Winter Moth (without adaptation)

Van Asch et al. GCB 2007
Predicted changes in Oak bud burst and in hatching date Winter Moth (with adaptation)

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

Winter moth egg hatching (April date) vs Temperature 1 Jan – 31 March
Response to selection on temperature sensitivity
Response to selection on temperature sensitivity

Field data
Response to selection on temperature sensitivity

Field data
Response to selection on temperature sensitivity

Field data
Response to selection on temperature sensitivity

Field data
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
How general are the findings for the winter moth?

Can species adapt to their warming world?

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*).