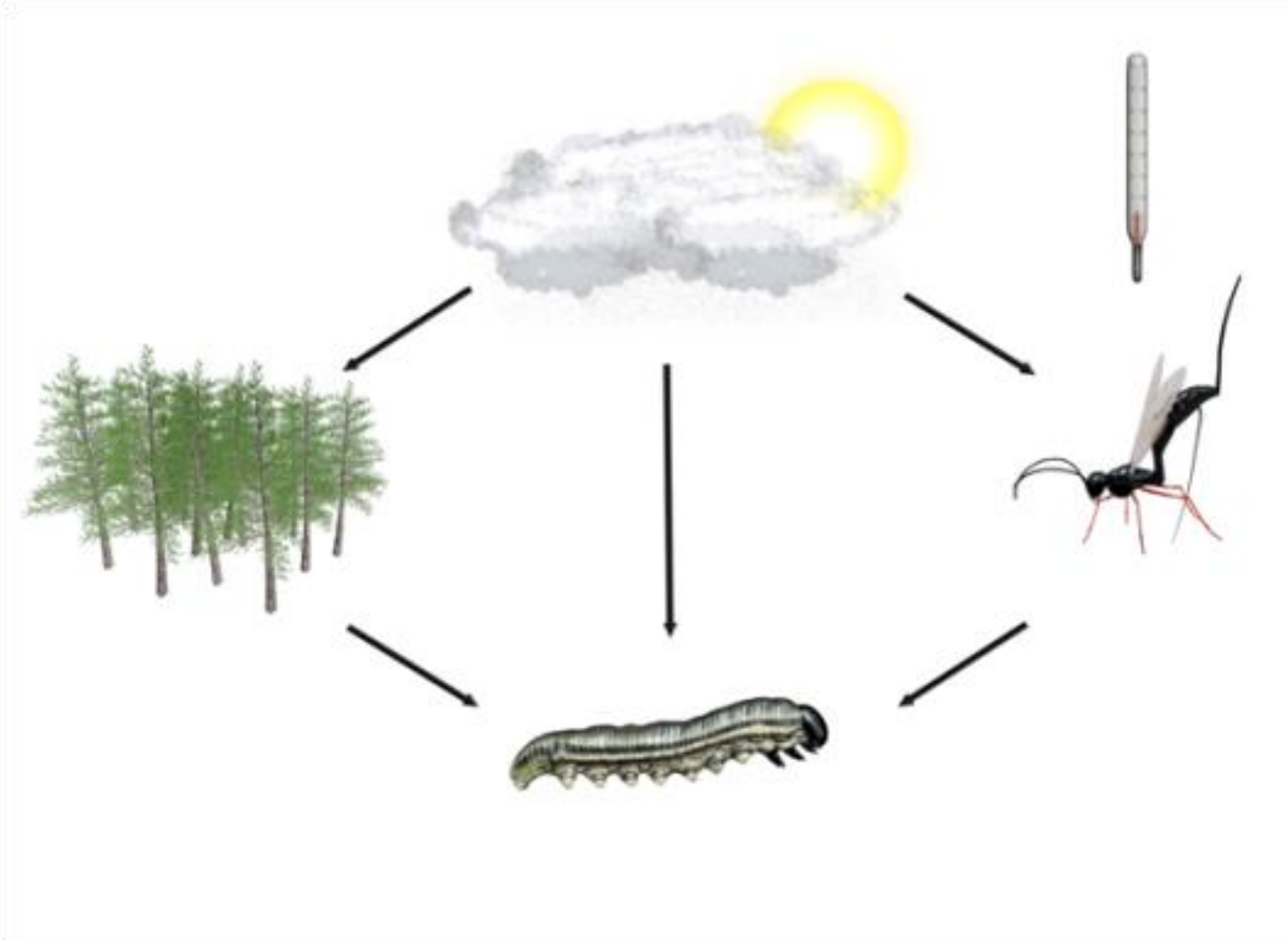
Learning objectives:

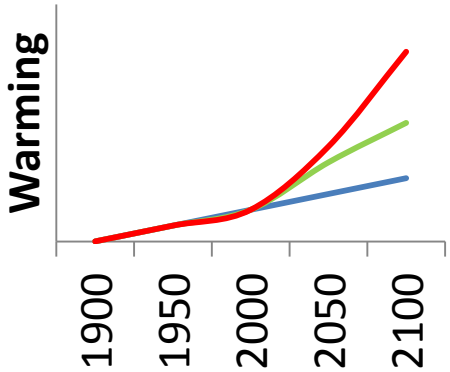
1. Biodiversity
2. Invasive species
3. Structure of forest insect communities and ecological guilds
4. Population dynamics of forest insect pests
5. How forest insects respond to abiotic drivers
6. How forest insects respond to biotic drivers: plant quality
7. How forest insects respond to biotic drivers: competition
8. How forest insects respond to biotic drivers: natural enemies
9. Ecological management of insect pest populations

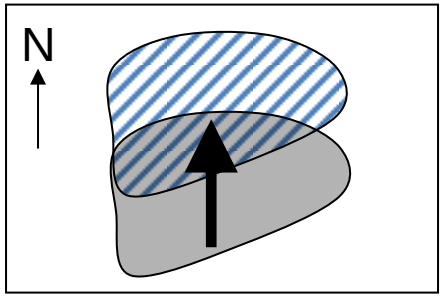
Insect outbreaks chapter 20

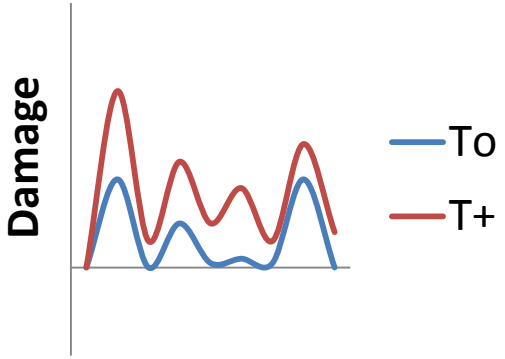
Temperature, radiation, moisture, precipitation (rain and snow), wind



How important are abiotic factors and climate change for frequency and distribution of insect outbreaks?

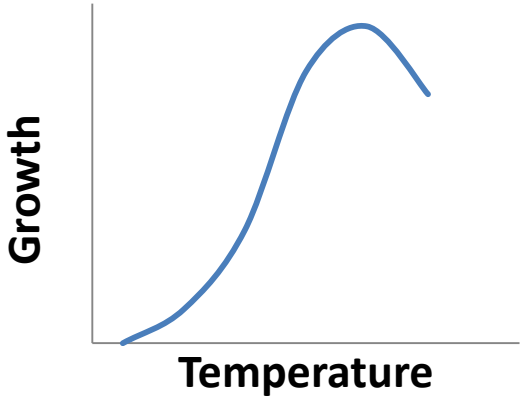






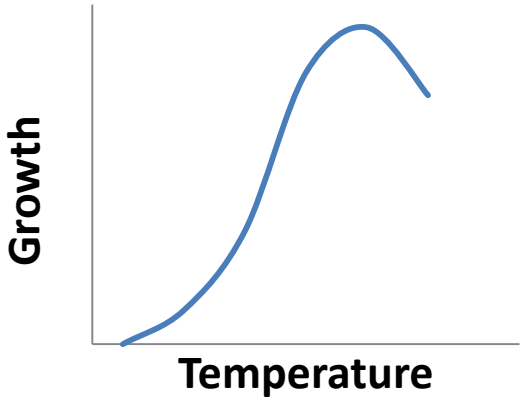
Direct and indirect responses

Direct responses of herbivores to temperature

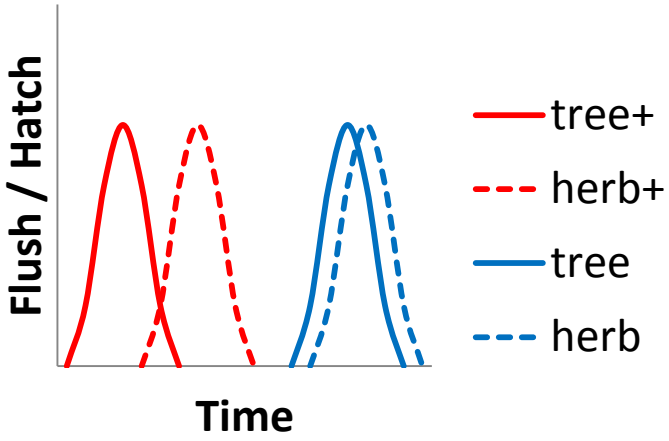


Direct and indirect responses

Direct responses of herbivores to temperature

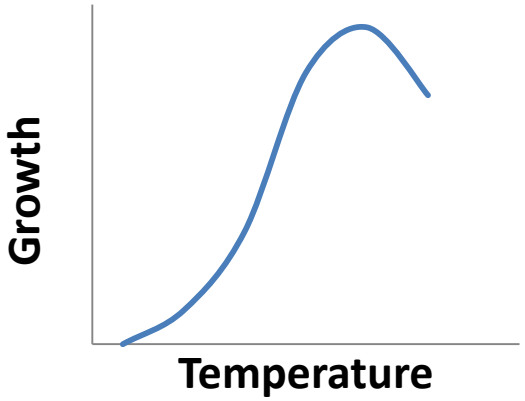


Indirect through host plant: how trees respond to cc and affect herbivores

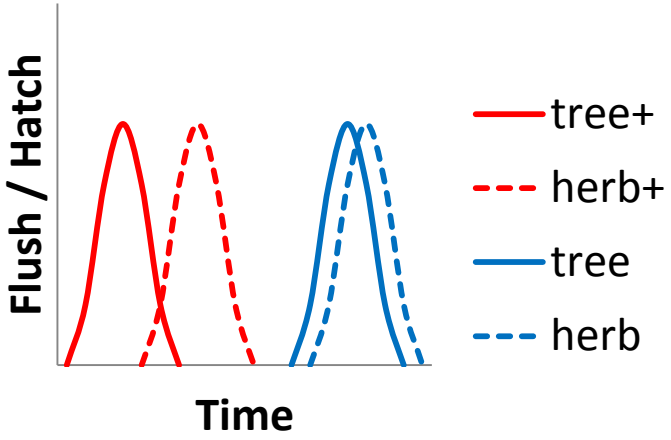


Direct and indirect responses

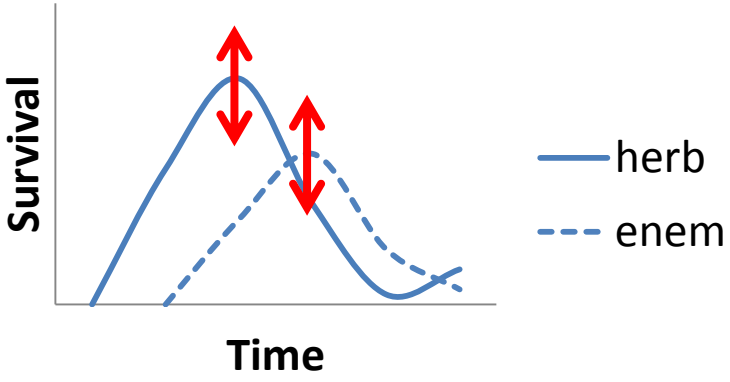
Direct responses of herbivores to temperature



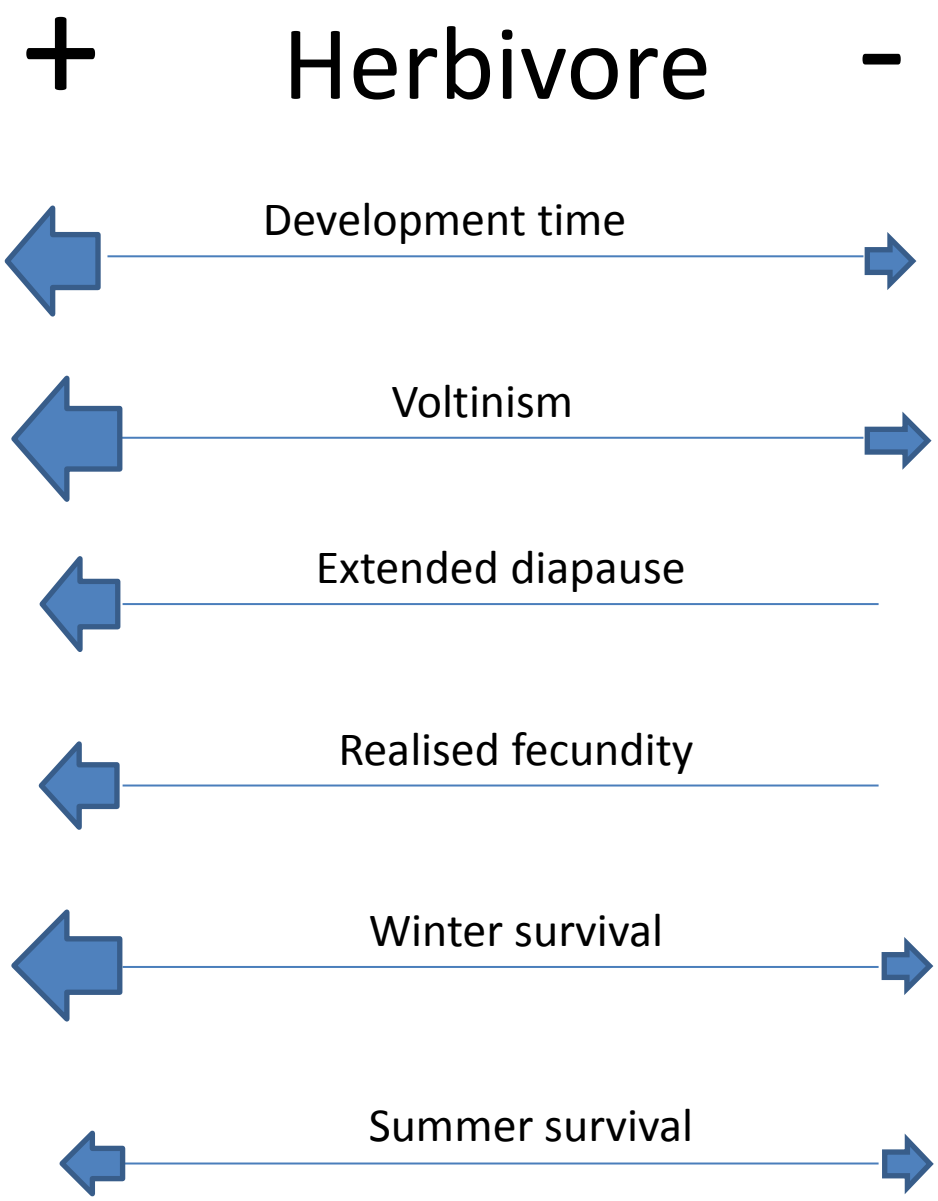
Indirect through host plant: how trees respond to cc and affect herbivores



Indirect through natural enemies: how parasitoid, predators and pathogens respond to cc and affect herbivores



Direct effects of climate change on



Direct effects of climate change on

+ Herbivore -

Development time

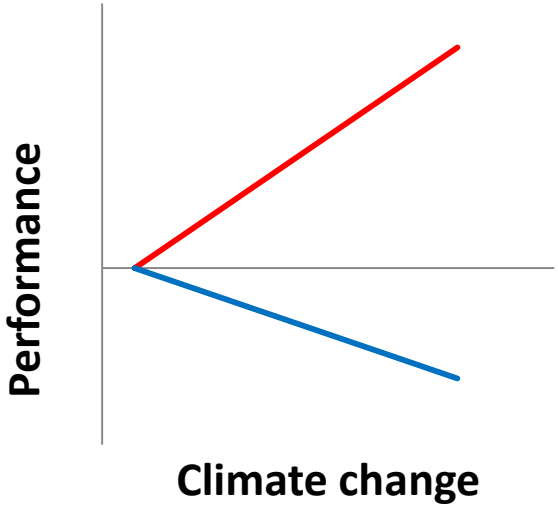
Voltinism

Extended diapause

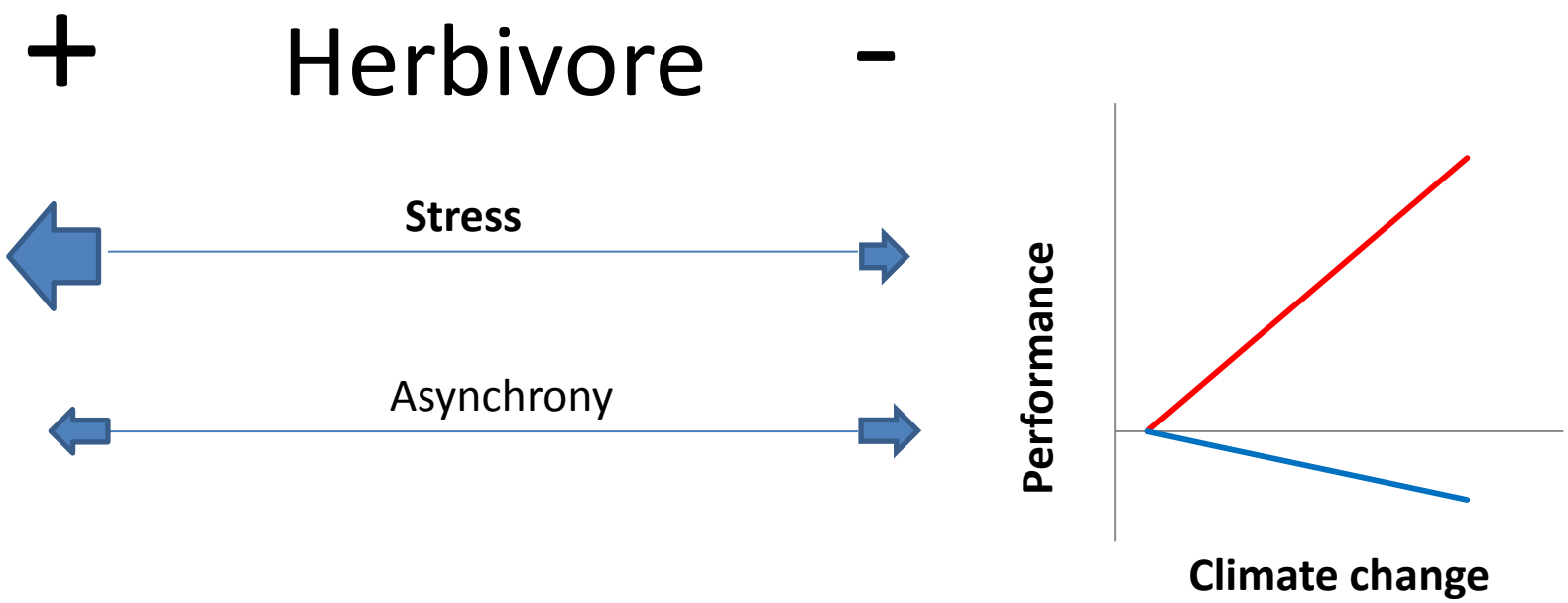
Realised fecundity

Winter survival

Summer survival

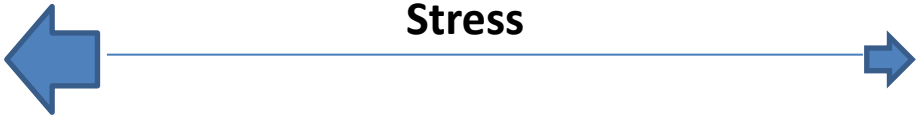


Indirect effects of climate change through host plant on

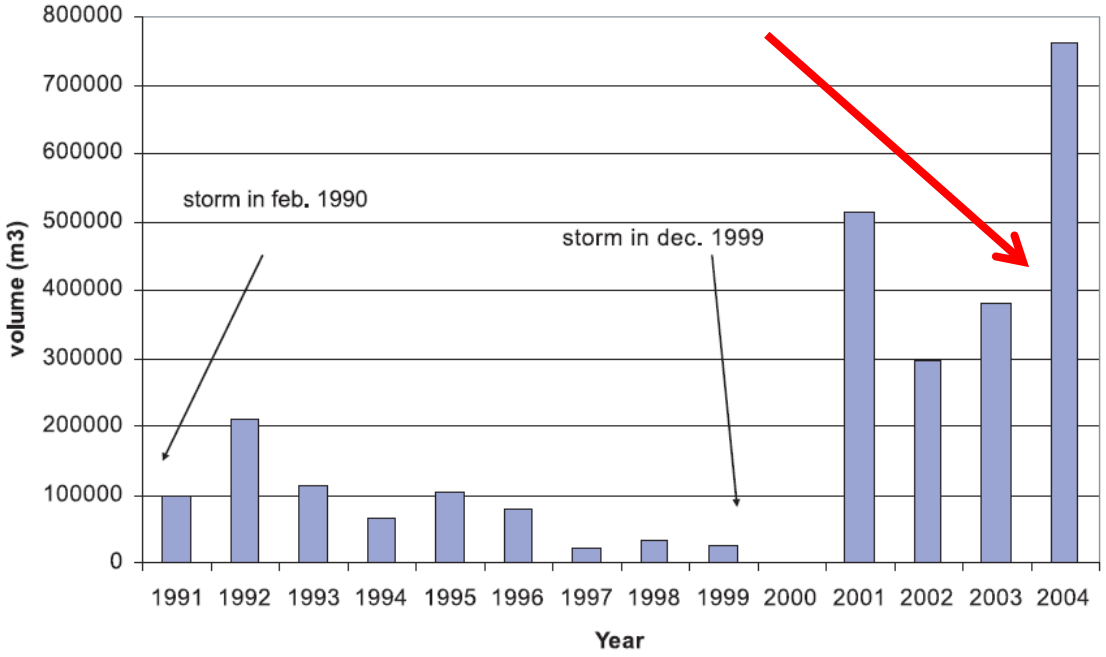


Indirect effects of climate change through host plant on

\+ Herbivore -



Summer 2003 and spruce bark beetle *Ips typographus* Rouault et al. (2006)



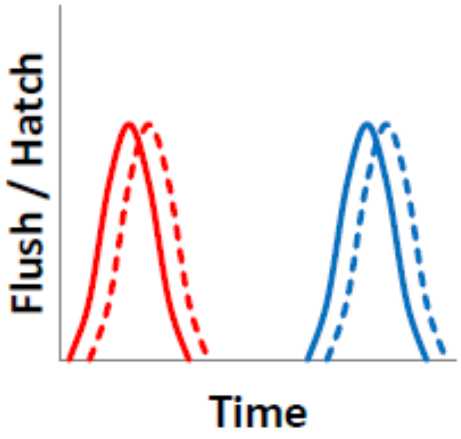
Indirect effects of climate change through host plant on

\+ Herbivore -

Host

Herbivore

Asynchrony



Egg overwinter on *Quercus*

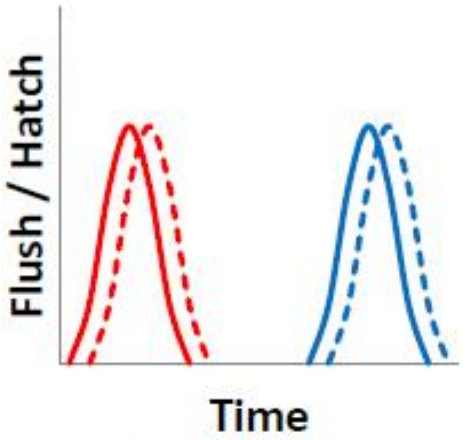
Indirect effects of climate change through host plant on

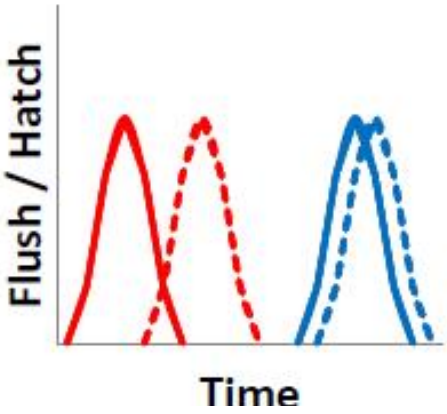
\+ Herbivore -

Host

Herbivore

Asynchrony





Egg overwinter on *Quercus*

Different reaction tree/herbivore

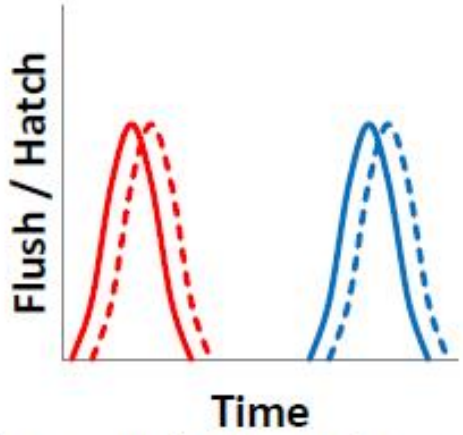
Indirect effects of climate change through host plant on

\+ Herbivore -

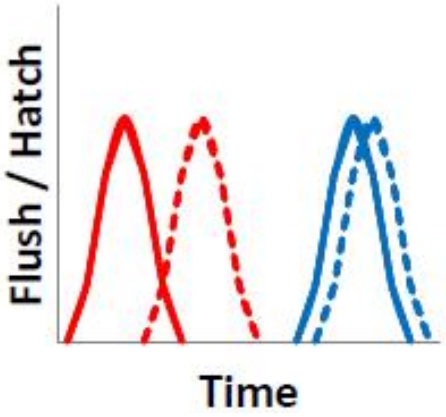
Host

Herbivore

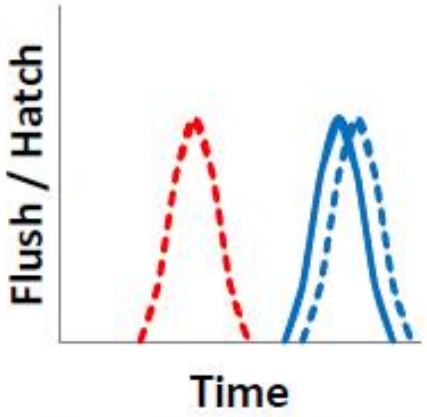
Asynchrony



Egg overwinter on *Quercus*



Different reaction tree/herb



Eggs overwinter on *Fagus*

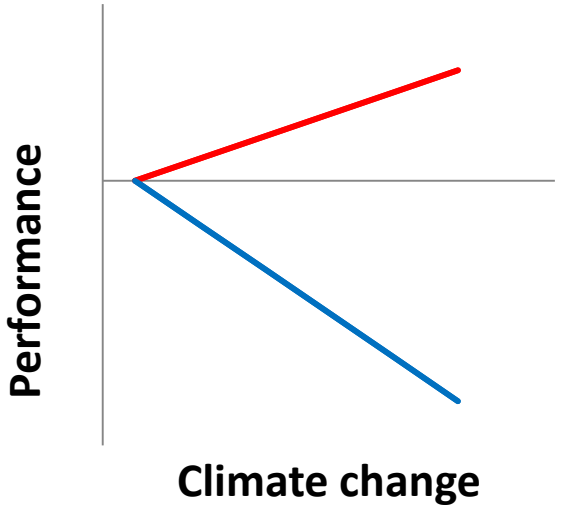
Indirect effects of climate change through natural enemies on

\+ Herbivore -

Arthropod fitness and behaviour

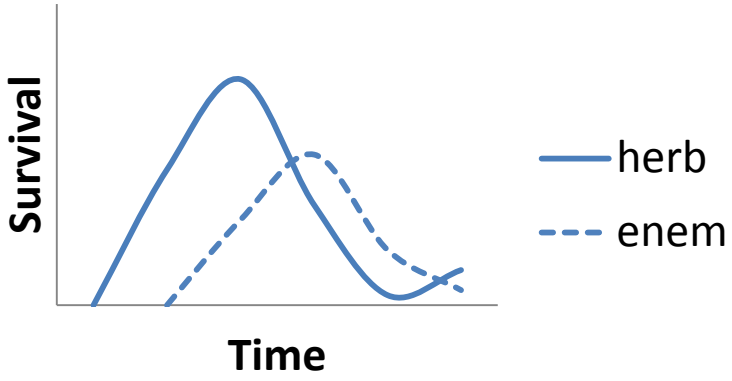
Voltinism

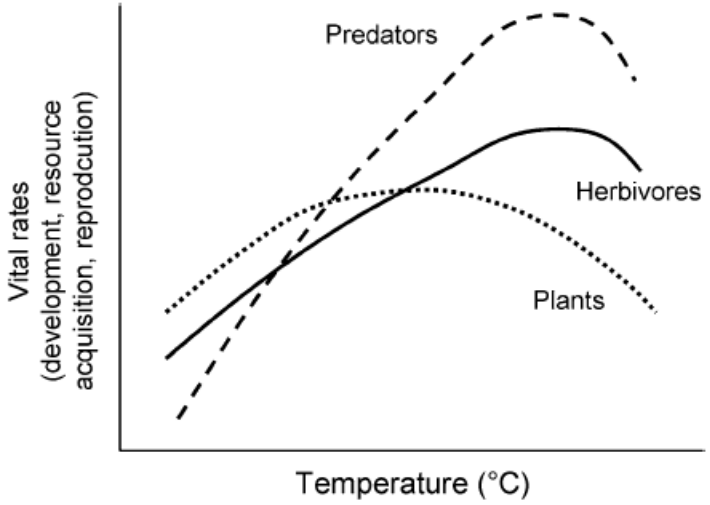
Intra-guild killing rate

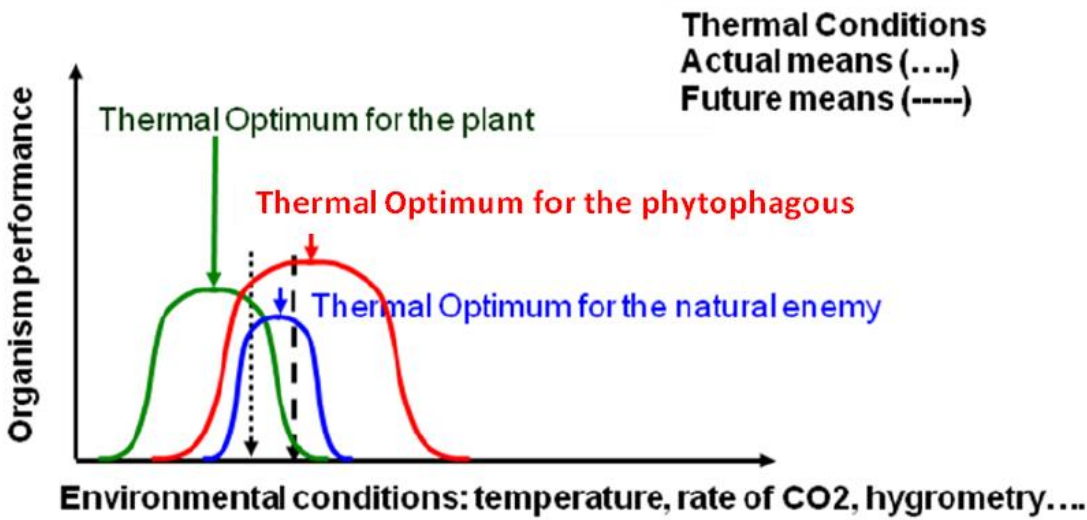


Natural enemies

Indirect through natural enemies: how parasitoid, predators and pathogens respond to cc and affect herbivores

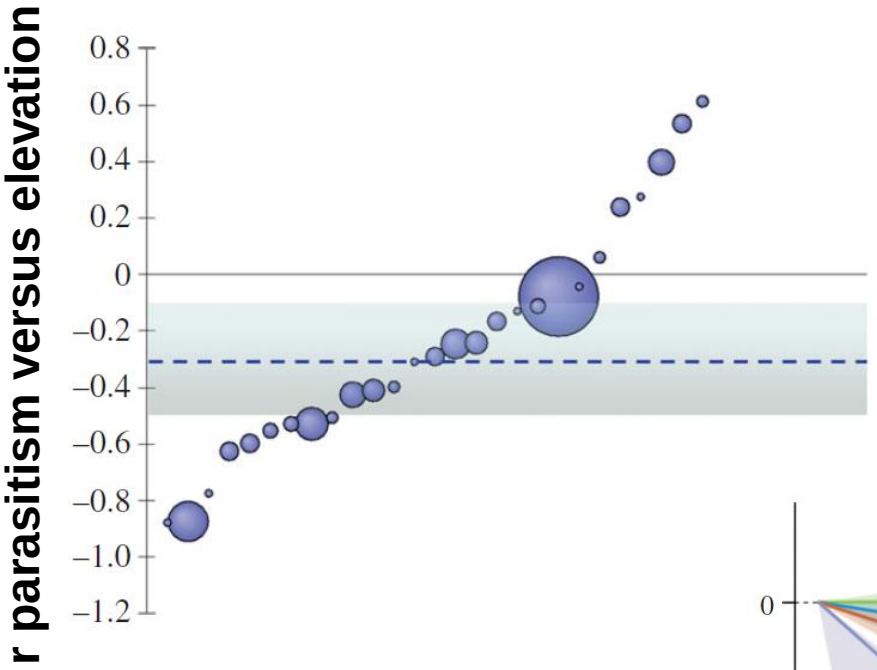


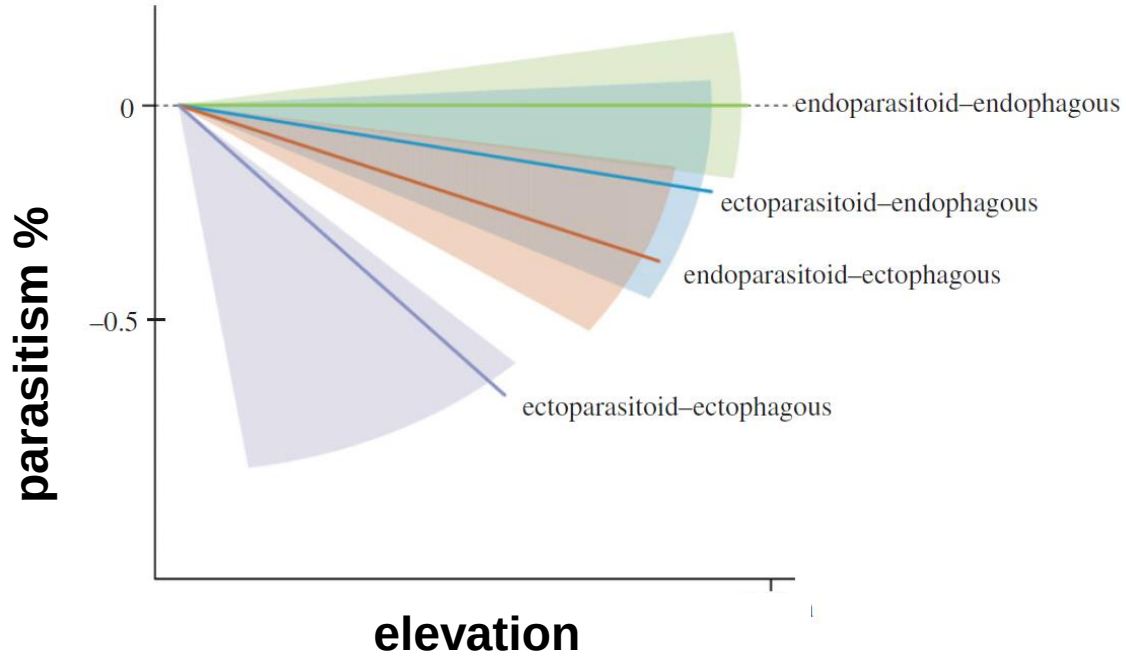




Berggren et al. 2009 vs van Baaren et al. 2010

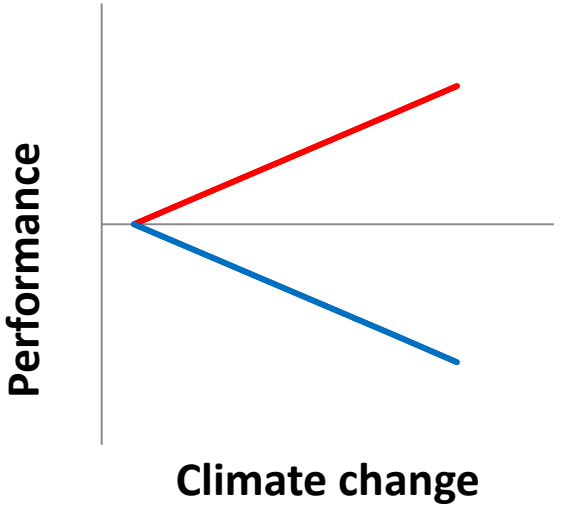
Indirect through natural enemies: meta-analysis of parasitism versus elevation
Péré et al. 2013 Biol Lett

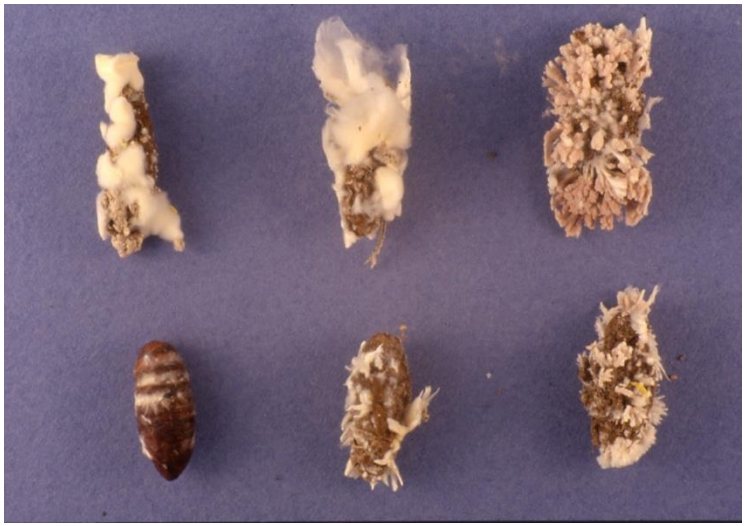




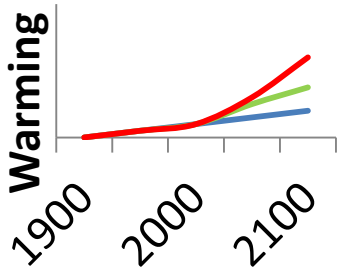
Indirect effects of climate change through natural enemies on

\+ Herbivore -





Summary of the action of climate change on trophic levels



CC

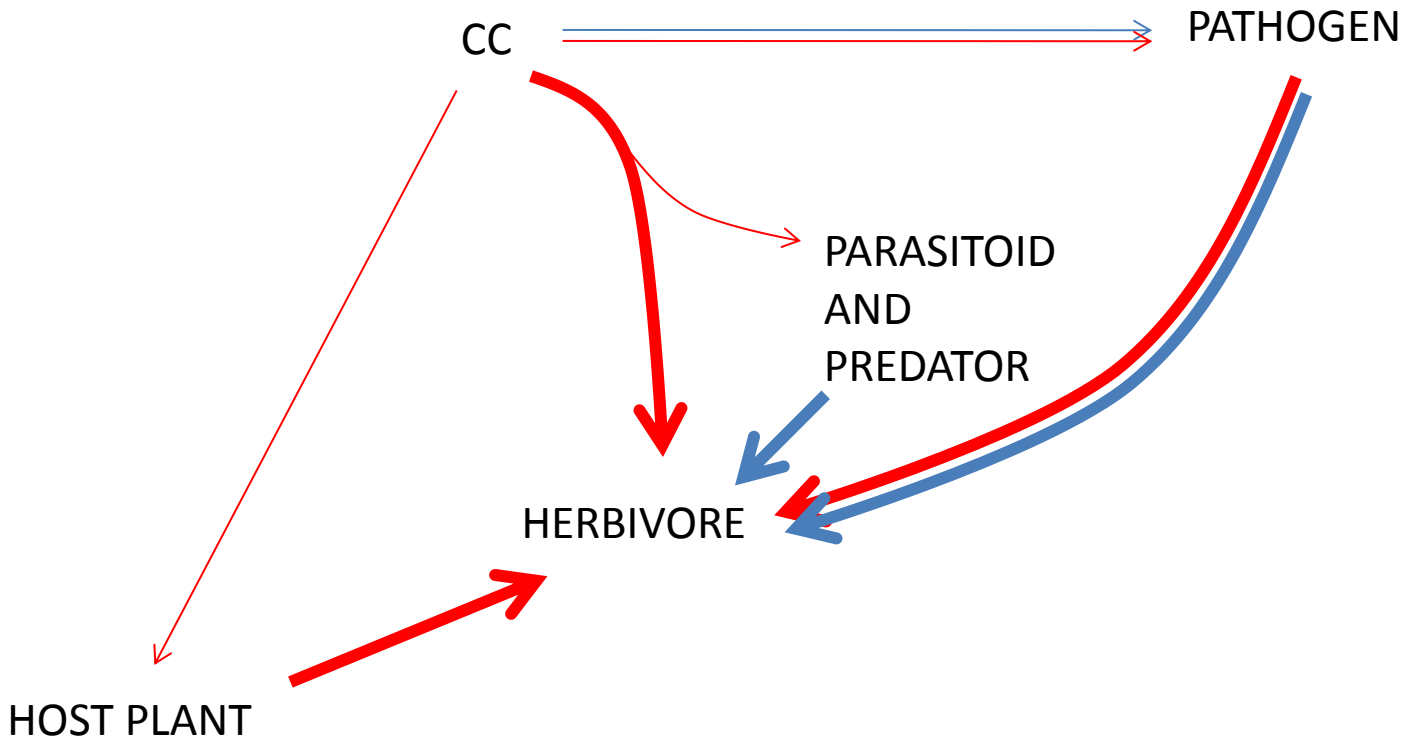
PATHOGEN

PARASITOID
AND
PREDATOR

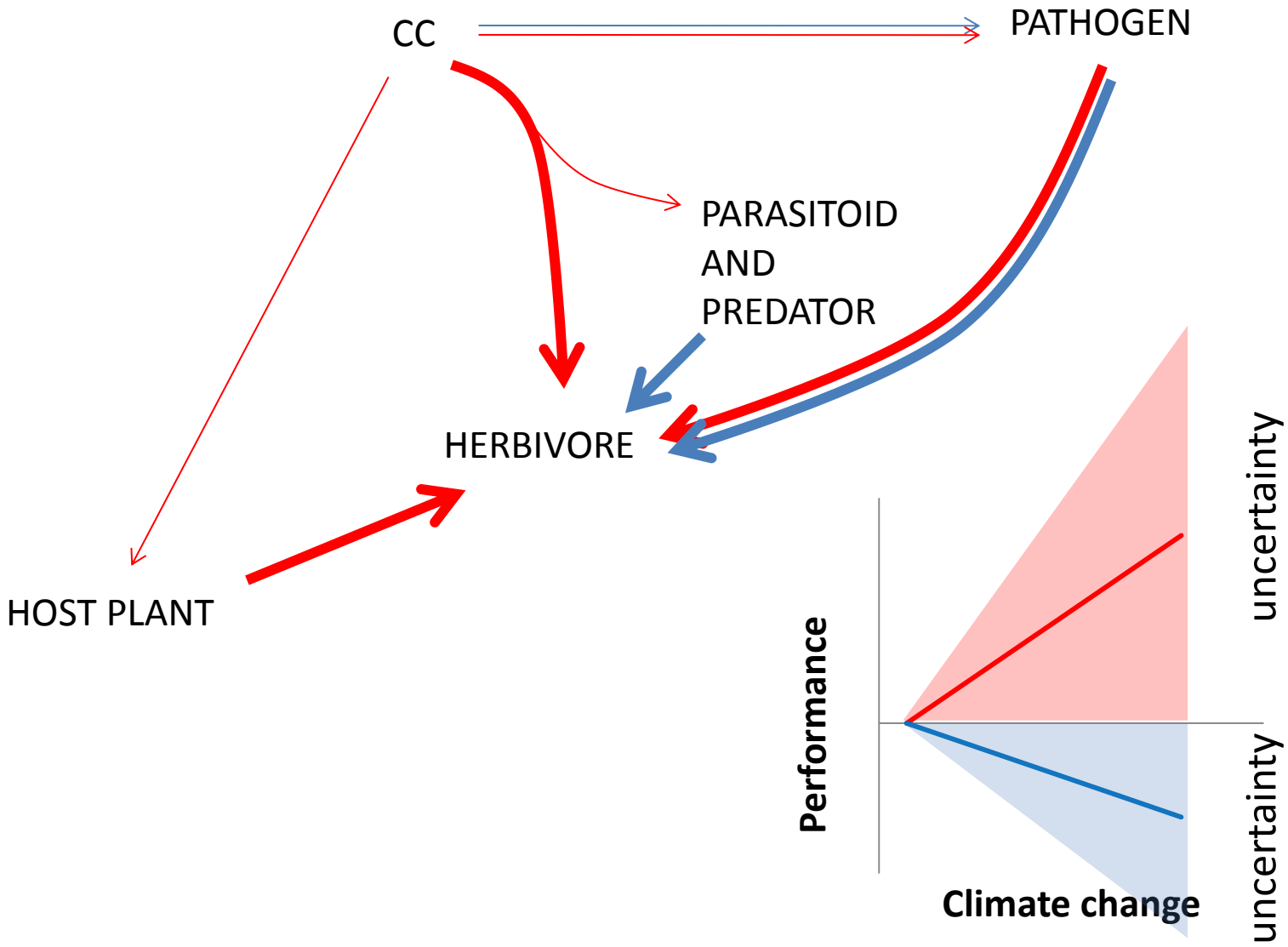
HERBIVORE

HOST
PLANT

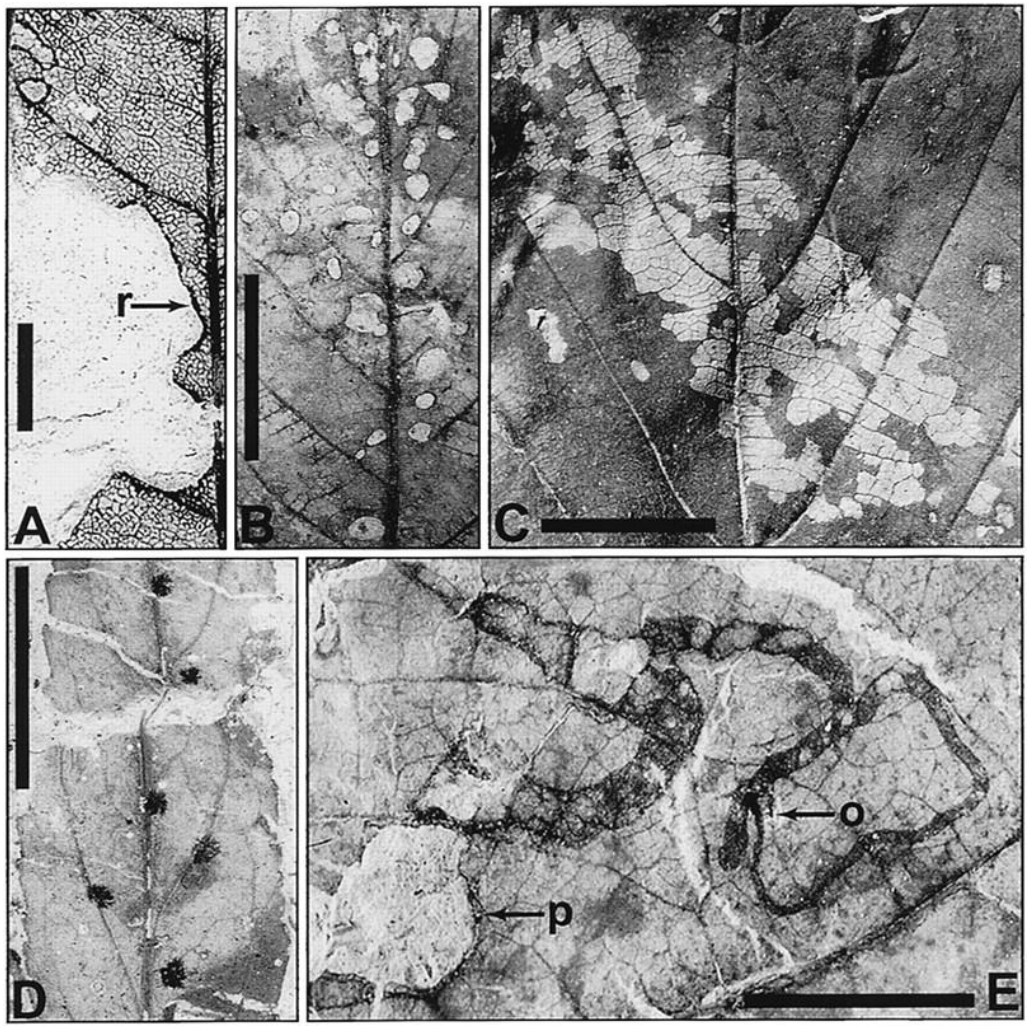
Direct and **indirect** effects of cc on herbivore performance



Direct and **indirect** effects of cc on herbivore performance



Insects and climate change: nothing new?



"Early Eocene plants [warmer climate] had more types of insect damage per host species and higher attack frequencies than late Paleocene plants"

Wilf and Labandeira. 1999. Response of Plant-Insect Associations to Paleocene-Eocene Warming. Science

Perspectives and research opportunities