Applied Evolutionary Ecology Part 5: Ecological and Evolutionary Responses to Recent Climate Change I

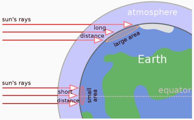
Michael Noonan

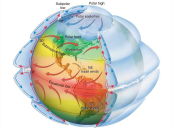
Biol 417: Evolutionary Ecology

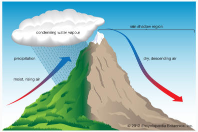
Table of contents

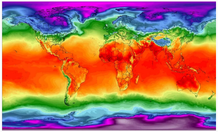
Review

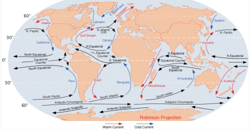
One of the first things we covered was how physics, combined with the Earth's geography work to govern climatological patterns.

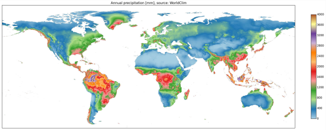






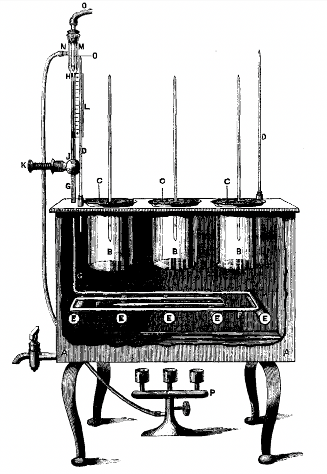






Review cont.

We also saw how species track environmental change and become adapted to their local conditions



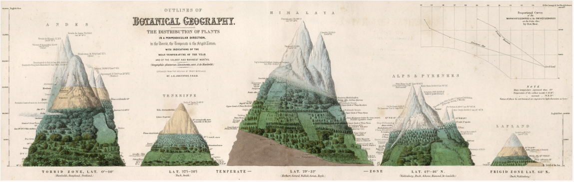
Source: Dallinger (1887)

Dallinger (1887) took a founding population of bacteria that grew between 15.5-18.3°C and reared them at steadily increasing temperatures.

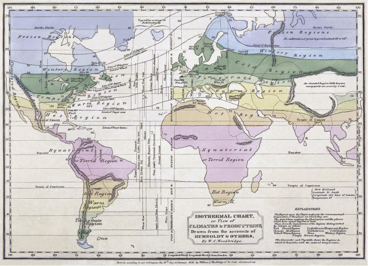
Adaptation: After 7 years the population thrived at 70°C.

Cost: The founding pop. died at 70°C and the evolved pop died at 15.5°C.

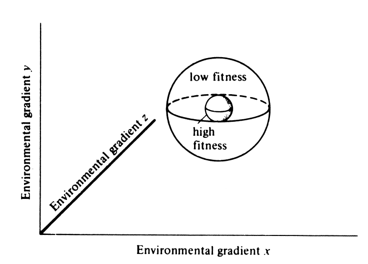
This leads to predictable patterns in ecosystem structure and composition (which we have studied for centuries).



Source: Wikipedia



Source: Wikipedia

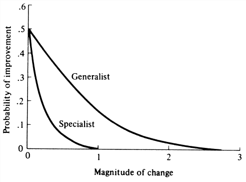


Source: Pianka (2000)

Review cont.

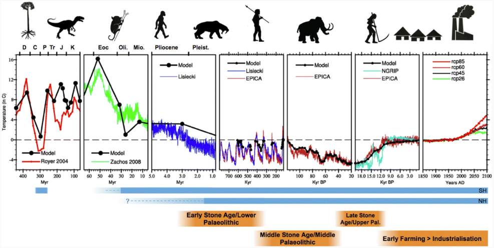
We know that species adapt to environmental change, so what makes human induced climate change so special?

Large, fast environmental change is *always* maladaptive (Fisher, 1958).

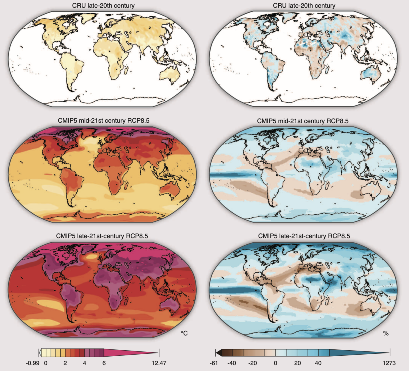


Source: Pianka (2000)

And CC is **both** of these...



Source: Haywood *et al.* (2019)



Diffenbaugh & Field (2013)

Climate change involves a shift towards globally warmer conditions with altered rainfall patterns (trends will differ regionally).

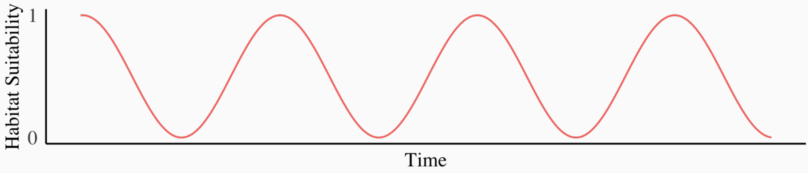
Global mean temperature has increased by ~1.1°C since the beginning of the 20th century.

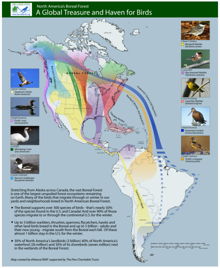
Conditions are also more variable with more extreme events.

Phenological Changes

Phenology

Phenology is the study of the relations between inter-annual variations in climate and periodic biological phenomena.

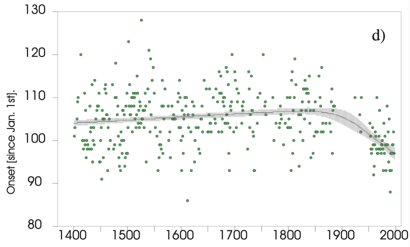




People living northern countries love spring, so we have records phenological records going back centuries.

The timing of the cherry blossoms in Japan has been documented for centuries.

There's a lot of noise from year to year but a breakpoint in the early 1900s.



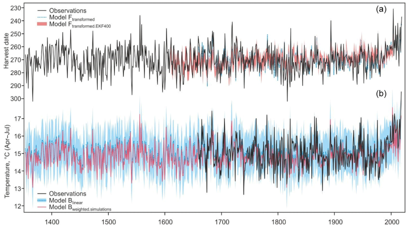
Menzel & Dose (2005)

Phenology cont.

People living northern countries love spring, so we have records phenological records going back centuries.

The timing of grape harvests in Europe has also been documented for centuries.

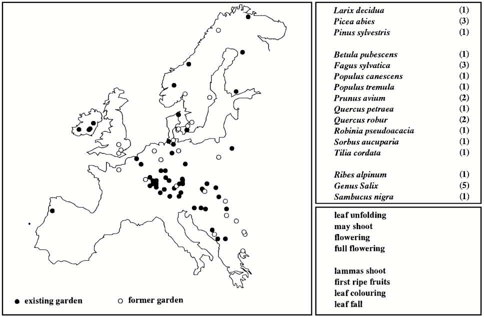
There's a lot of noise from year to year but a breakpoint in the late 1900s.



Labbé *et al.* (2019)

Phenological Gardens

In 1959 Europe established the International Phenological Gardens, which has clones of 16 species distributed across the continent.



Location of the International Phenological Gardens / Program of observation

Menzel (2000)

Menzel (2000) found that the growing season has become 10.8 days longer since the gardens were established.

Parmesan & Yohe (2003) reviewed data on the distributions and phenologies of 1598 globally distributed species over the past 20-140 years.

They found that ca. 59% showed evidence of a response to climate change.

Spring phenological responses were, on average, 2.3 days earlier per decade.

Source: Red-tail Land Conservancy

Phenological Responses

The steady advance of spring events (bud burst, flowering, breaking hibernation, migrating, breeding) has been documented across the globe and in all major oceans for all well-studied marine, freshwater, and terrestrial groups.

This suggests that species are adapting to the novel conditions caused by CC, so why should we be concerned?

A species' niche is more than just its place in abiotic space (i.e., the Grinnellian niche). Biotic interactions are an important part of species' niches (Eltonian/Hitchinsonian niches), and no two species are likely to respond to CC in the same way and at the same rate.

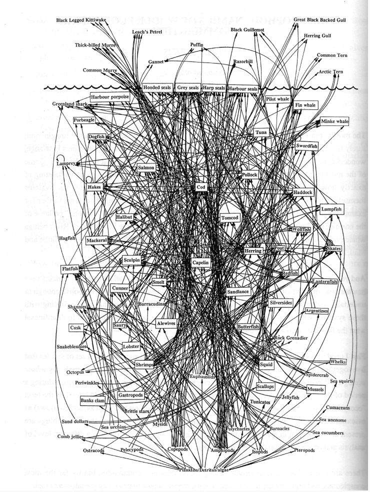
Phenological Responses and Ecological Synchronicity

Phenological Responses

All species living in the same environment are exposed to the same level of CC, but have different ecological niches, constraints, and evolutionary rates.

Community dynamics are incredibly complex networks of interactions.

If interacting pairs respond in different directions or at different rates, normally synchronous phenologies can become decoupled.



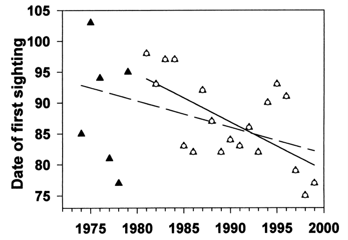
Source: Prof. David Lavigne

Migration timing

American robins (*Turdus migratorius*) use air temperature to time their annual migration.

Source: Wikipedia

Inouye *et al.* (2000) found that robins are arriving at their summer grounds earlier, but the growing season hasn't changed.



(Inouye *et al.*, 2000)

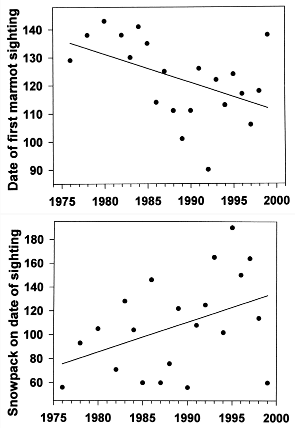
... leading to the interval between arrival date and the first date of bare ground having grown by 18 days.

Dormancy timing

Yellow-bellied marmots (*Marmota flaviventris*) use air temperature to time their emergence from hibernation.

Source: Wikipedia

Dissociation between air temperature and date of snow melt at high altitude locations leaves them out of sync with environmental conditions.



(Inouye *et al.*, 2000)

Energetic Balance

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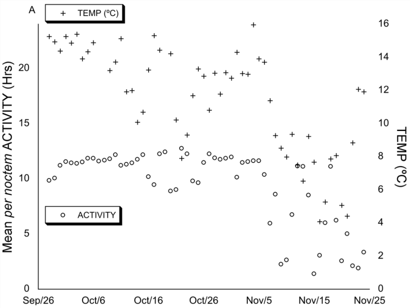
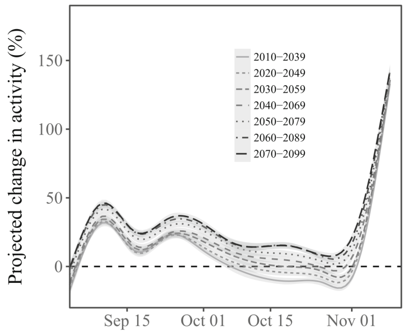
European badgers (*Meles meles*) adjust their nightly activity based on weather conditions.



(Noonan *et al.*, 2014)

Noonan *et al.* (2018) found that the conditions expected under CC would lead to increased autumnal activity, which could necessitate up to a 15% increase in energy expenditure.



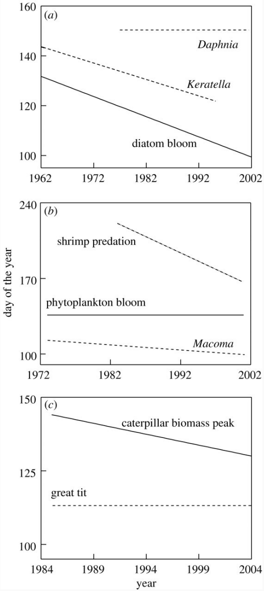
(Noonan *et al.*, 2018)

Phenological Synchronicity

Visser & Both (2005) reviewed cases where species interactions and CC were well documented (only 11 at the time).

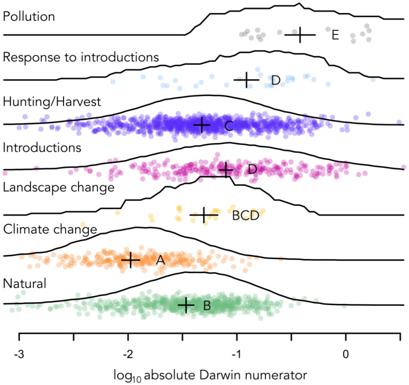
In most cases species shifted their phenology either by too little ($\frac{5}{11}$) or too much ($\frac{3}{11}$).

They concluded that many species interactions are becoming mistimed due to climate change.



Visser & Both (2005)

Adaptations to Climate Change



Sanderson *et al.* (2022); units: proportional change in the mean trait value per million years

Sanderson *et al.* (2022) reviewed 7338 estimates of phenotypic change and found that responses to CC were the slowest.

"...climate change can be a particularly noisy environmental driver..."

Species can respond to 'clean' trends, but the CC trend is noisy and difficult to respond to.

CC Phenology Take Homes

Species have well-defined niche spaces that have evolved over generations to allow them to survive and reproduce.

Large, fast change is always maladaptive and climate change is both large and fast and breaks the association between species' niches and their local climate.

Species across the global are shifting their phenologies to become better matched to novel conditions.

... but no two species are likely to respond to CC in the same way and at the same rate and community-level asynchrony is an important threat to species' survival.

We will continue with CC next lecture...

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