Effects of climate change on ecosystems

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Outline

- What is an ecosystem?
- What makes plants and animals tick?
- Effects of climate change on ‘natural ecosystems’
- Alien species
- Managed ecosystems

What is an ecosystem?

- A community of plants, animals and micro-organisms, along with their environment, that function together as a unit

- An ecosystem can be as large as a rain forest or as small as a rotting log

From WWF

What do we mean by biodiversity?

- All hereditarily based variation at all levels of organisation, from the genes within a single local population or species, to the species composing all or part of a local community, and finally to the communities themselves that compose the living parts of the multifarious ecosystems of the world.

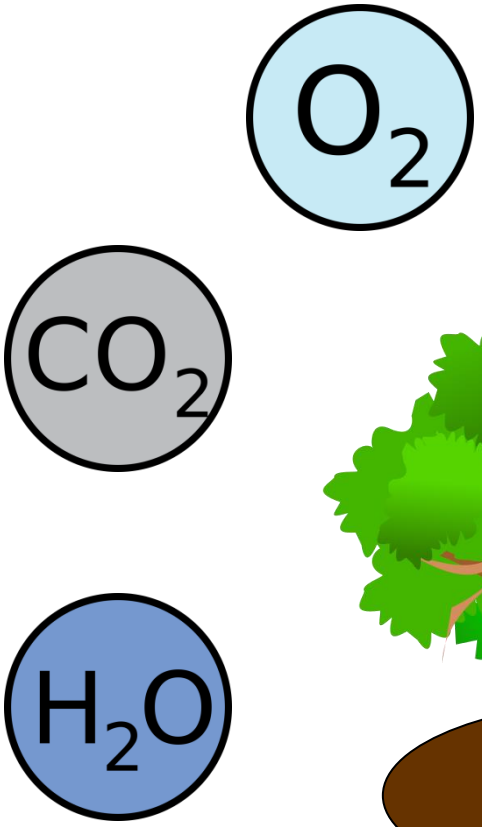
E O Wilson

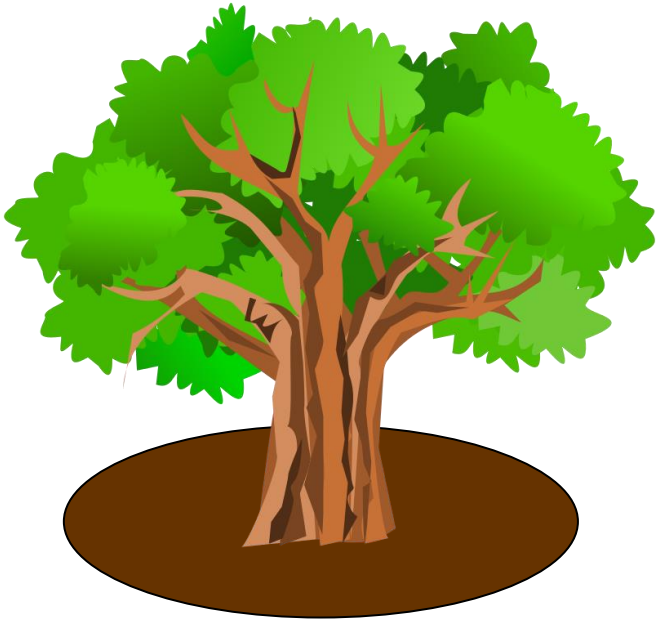
What is an ecosystem?

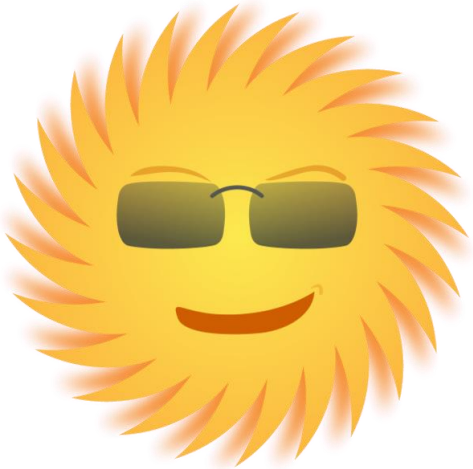
- https://www.youtube.com/watch?v=WuejxJttBqo

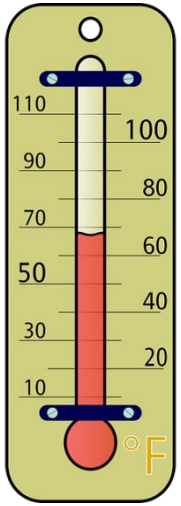
Crash course in biology

What makes plants tick?

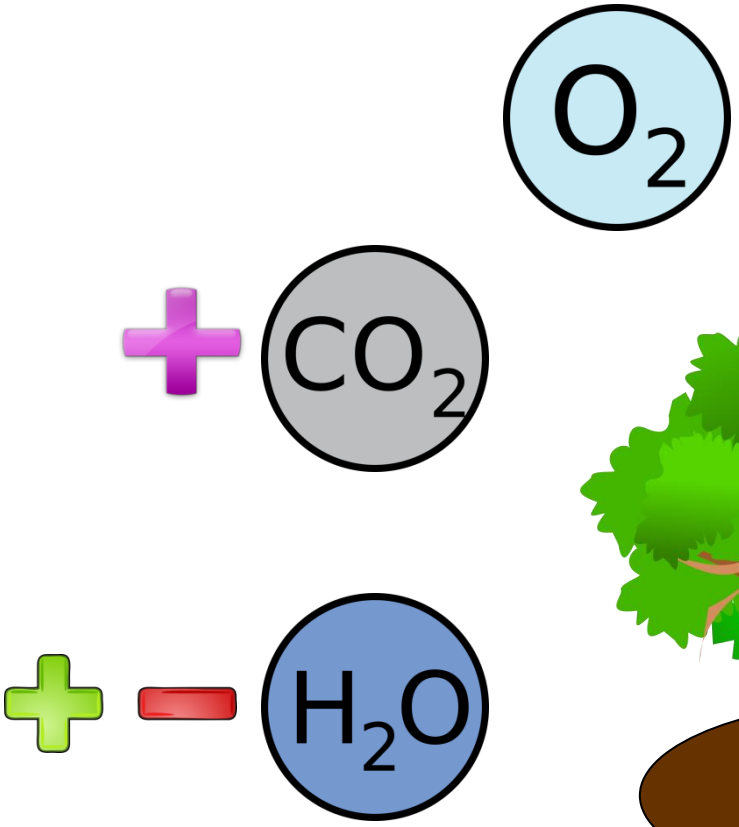


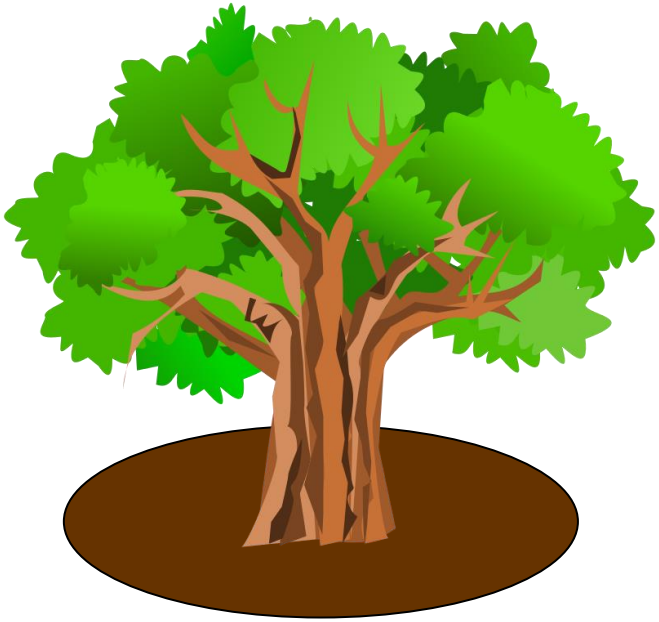


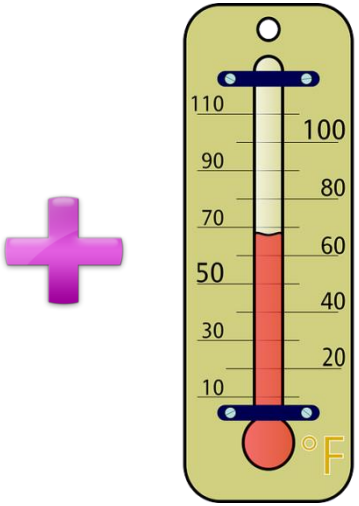




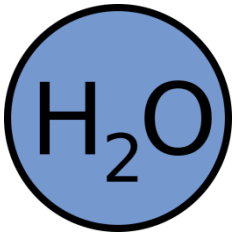
Effects of climate change?

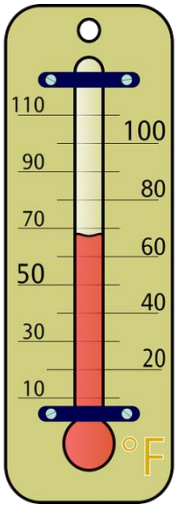




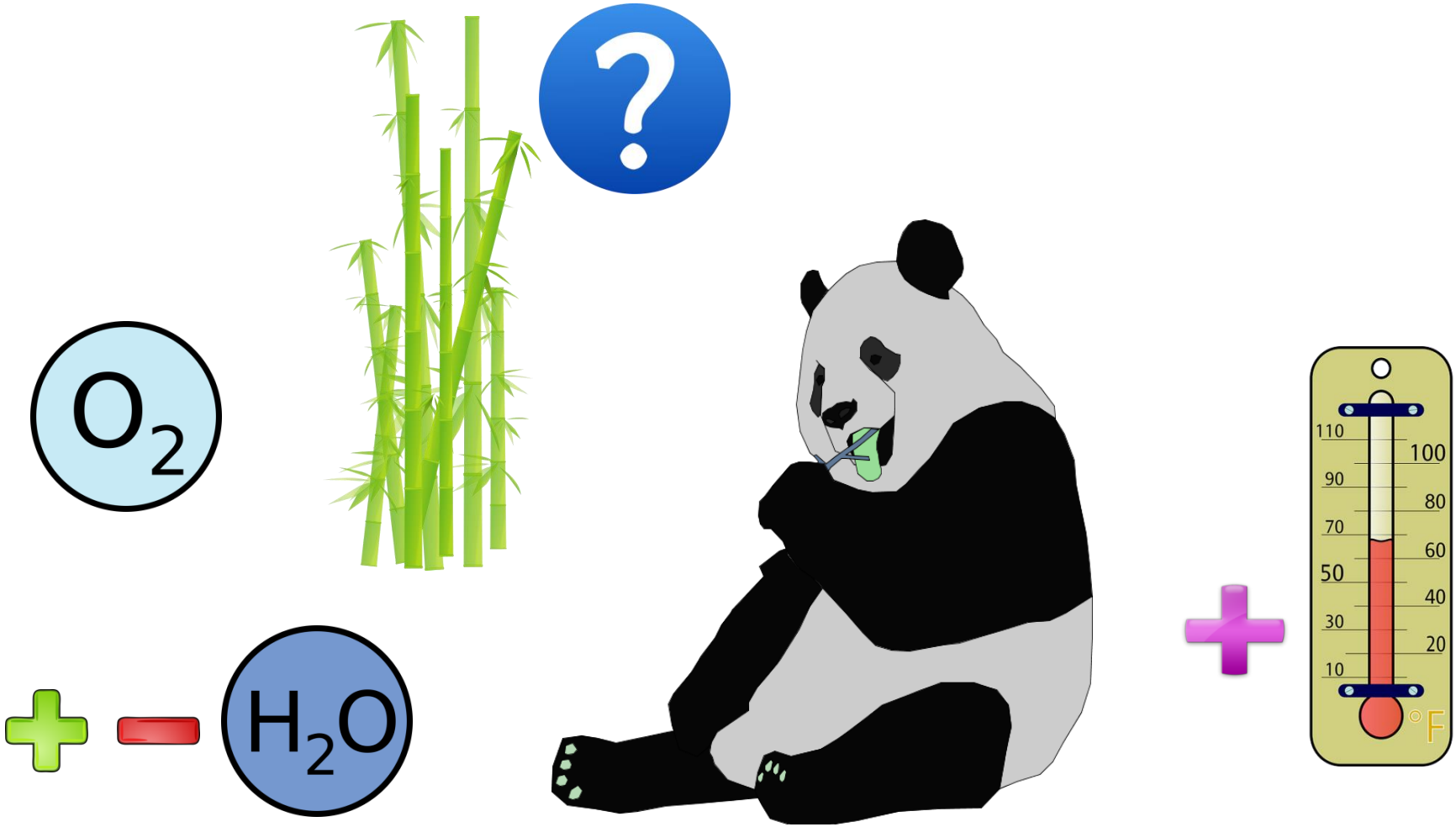


What do animals need?

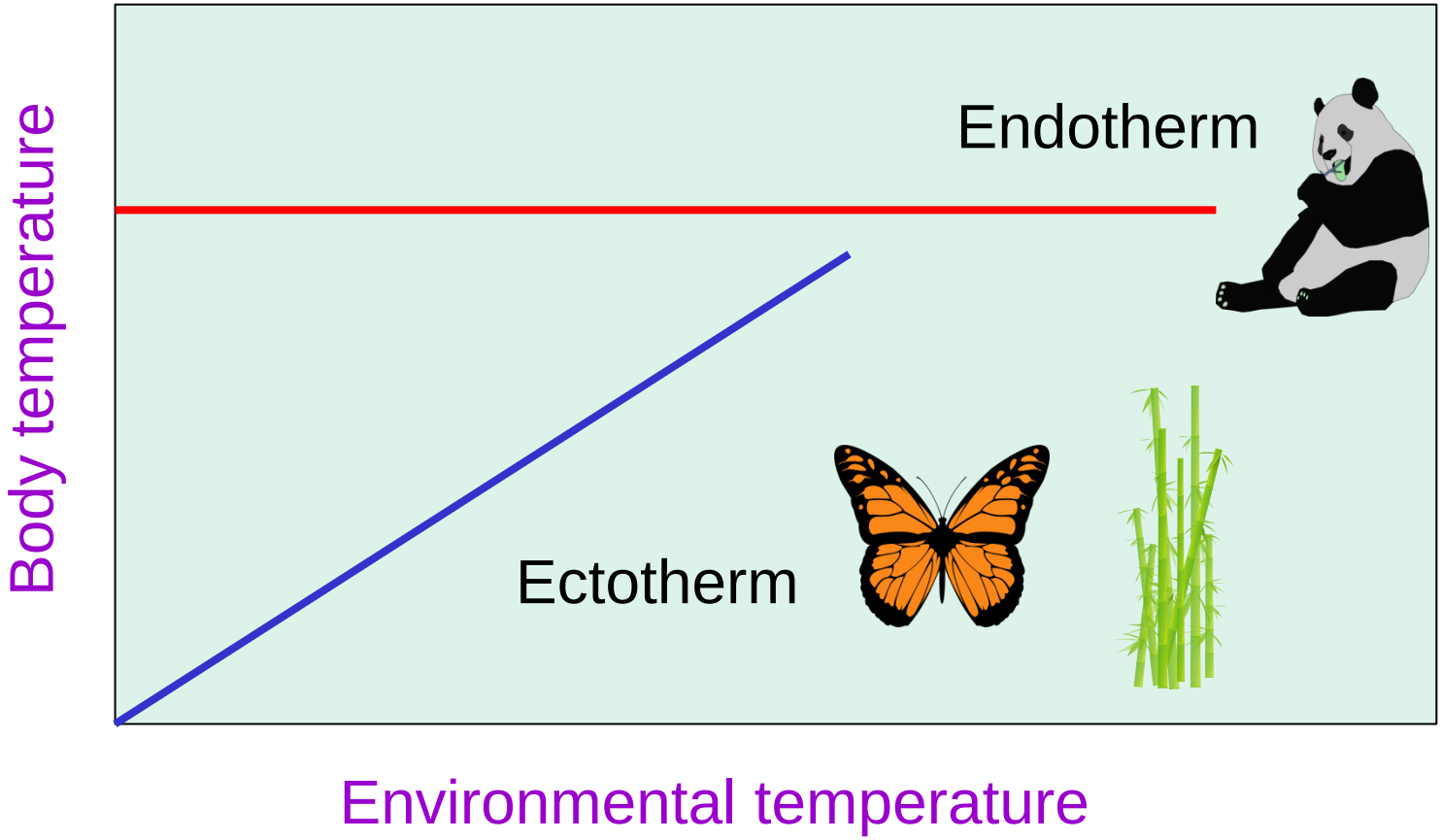




Effects of climate change?



Endotherms and ectotherms



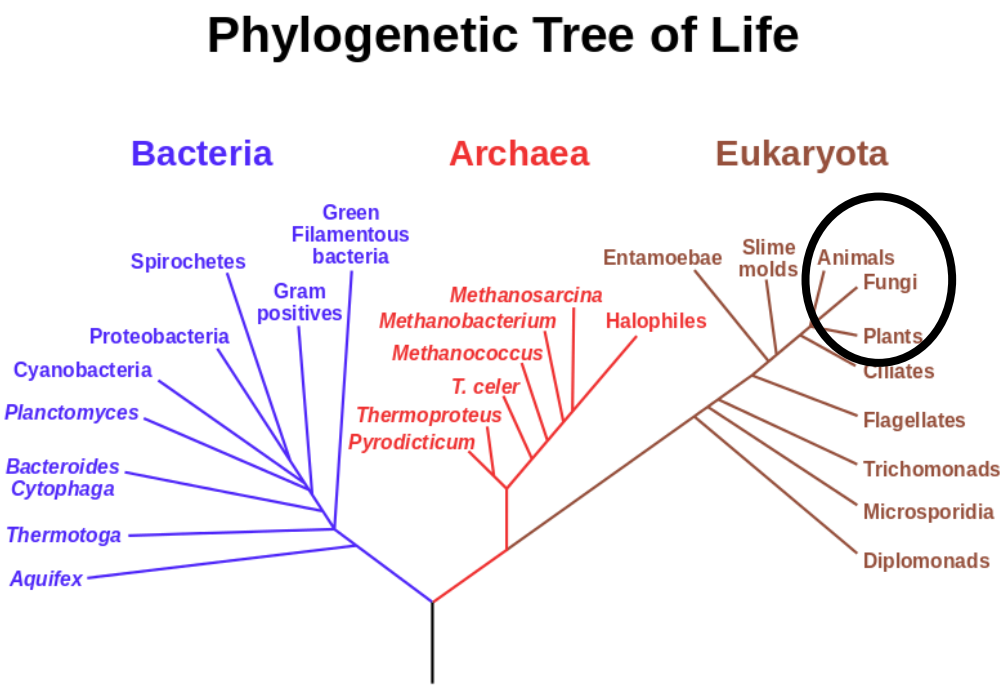
Can you think of other groups of:

- Endotherms?
- Ectotherms?

Other organisms

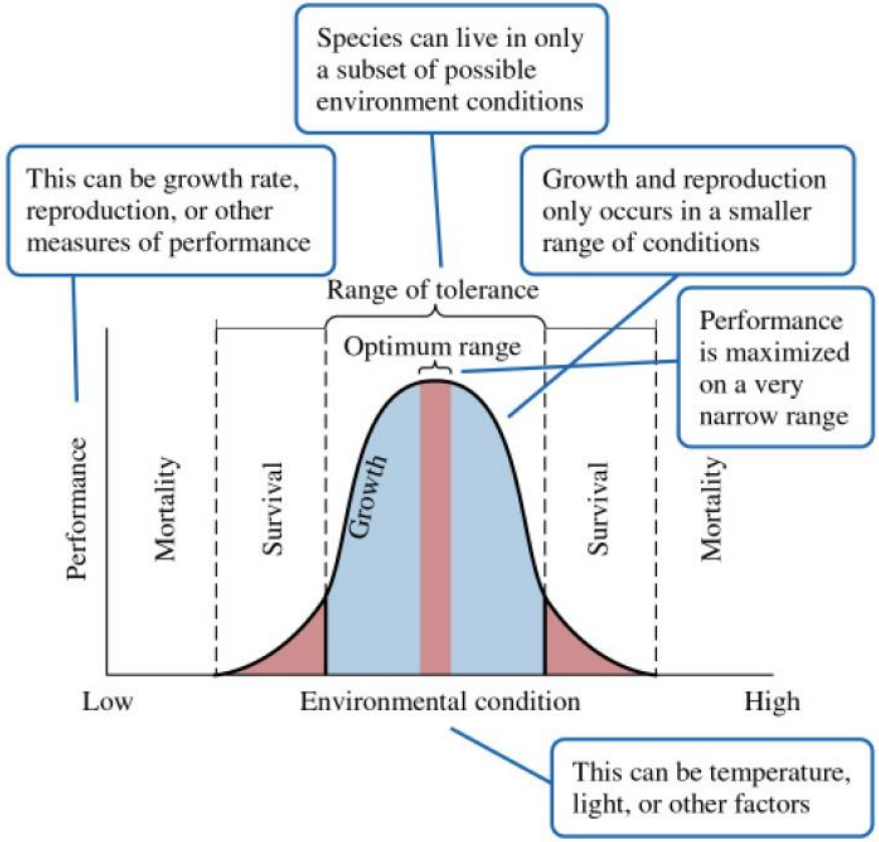
- Development, survival and reproduction of all these organisms will be affected in some way by temperature and some also by ‘moisture’

- For many - their generation times will be entirely dependent on environmental conditions as above. Daylength can also be a factor.



Thermal tolerance

Many organisms exist and function within a defined temperature range



©http://www.biology.ualberta.ca/courses.hp/bio208/Lecture_Notes_files/Biol208_Lecture10_TemperatureRelations2PP.pdf

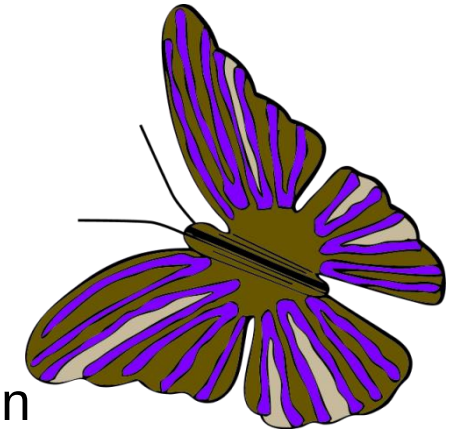
Effects of climate change on plants

- May increase growth through increased CO_2
- May change growth rate through increased temperature – this may increase or decrease depending on the optimum range for the species
- May expand or change geographical range of plant species – due to changes in temperature and/or precipitation

Effect of increased CO_2

- Increases in CO_2 levels have direct impact on plant performance
- Plants classified depending on whether carbon fixed directly in same cells and at same time as light energy is captured (C3) or whether these processes are separated within the leaf or at different times in the daily cycle
- Under current conditions of approx 400 ppm, C3 plants limited in photosynthetic potential by concentration of CO_2. Thus, increasing the concentration of CO_2 has the potential to stimulate photosynthesis in these species
- In practice, experiments growing crops at elevated CO_2 show that increase in rates of photosynthesis frequently not fully translated into increased yields as plants acclimate to higher levels through variety of mechanisms

Effects of climate change on non-plant ectotherms



- May increase growth rate and reduce generation time through increased temperature
- May decrease growth rate and increase generation time through increased temperature
- May increase or decrease survival due to changes in temperature and/or precipitation
- May expand or change geographical range of species – due to changes in temperature and/or precipitation

Effects of climate change on endotherms

- May alter food supply
- May make it easier to overwinter – warmer weather
- May expand or change geographical range – due to changes in temperature and/or precipitation and effects on food supply etc

Little Egret and UK

Phenology

- Timing of seasonal activity of animals and plants

http://www.naturescalendar.org.uk/

Recent advances in timing of spring events

Taxon	Location	Changes per decade
Plant species (many)	Europe, N. America	Flowering and foliage 1-3 days earlier
18 butterfly species	UK	Earlier appearance about 3 days
Amphibians	UK	Earlier breeding
Bird species (many)	Europe, N. America	Earlier spring migration 1-4 days Earlier breeding 2-5 days

Source: Walther et al., 2002

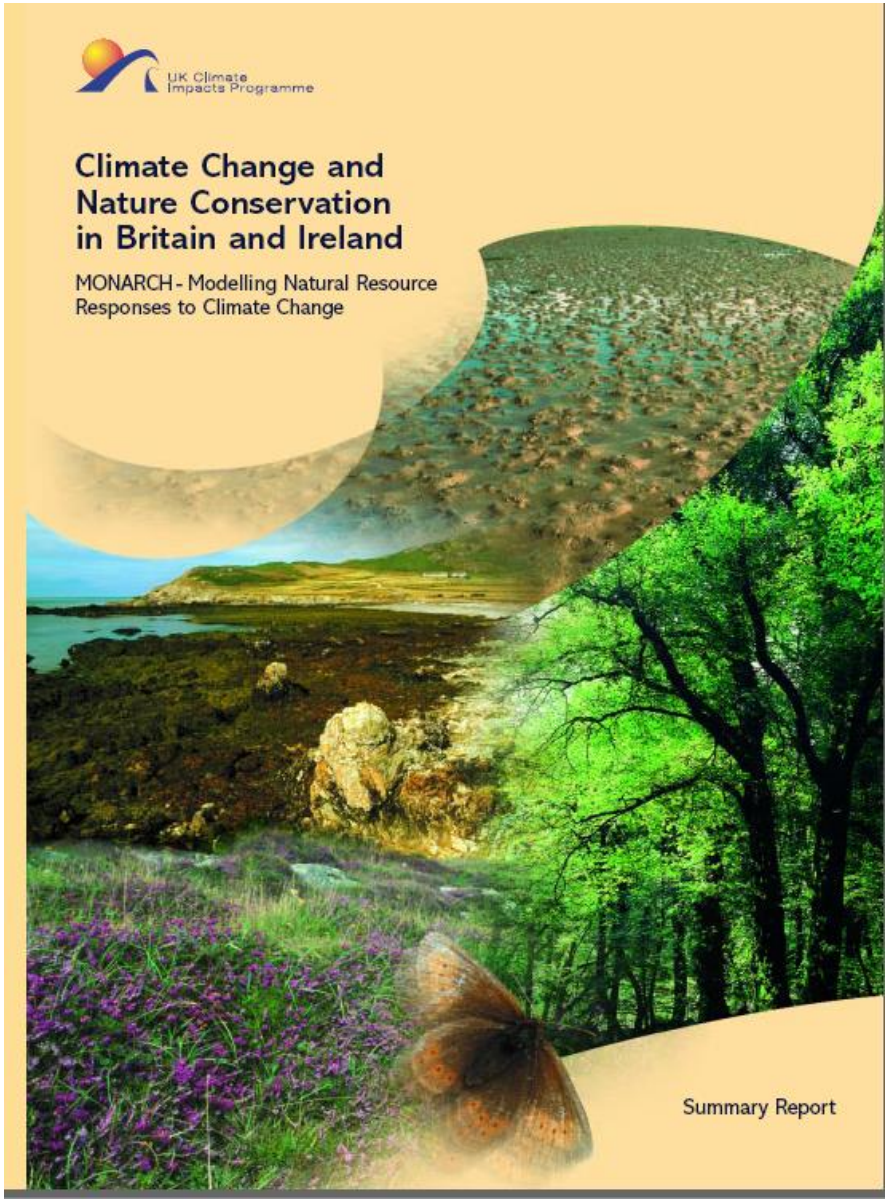
Climate envelopes

- Climatic conditions influence distribution of species, often because of species-specific physiological thresholds of tolerance to temperature and precipitation.

- With climate change (higher temperatures) these ‘climate envelopes’ shift towards the poles or to higher altitudes

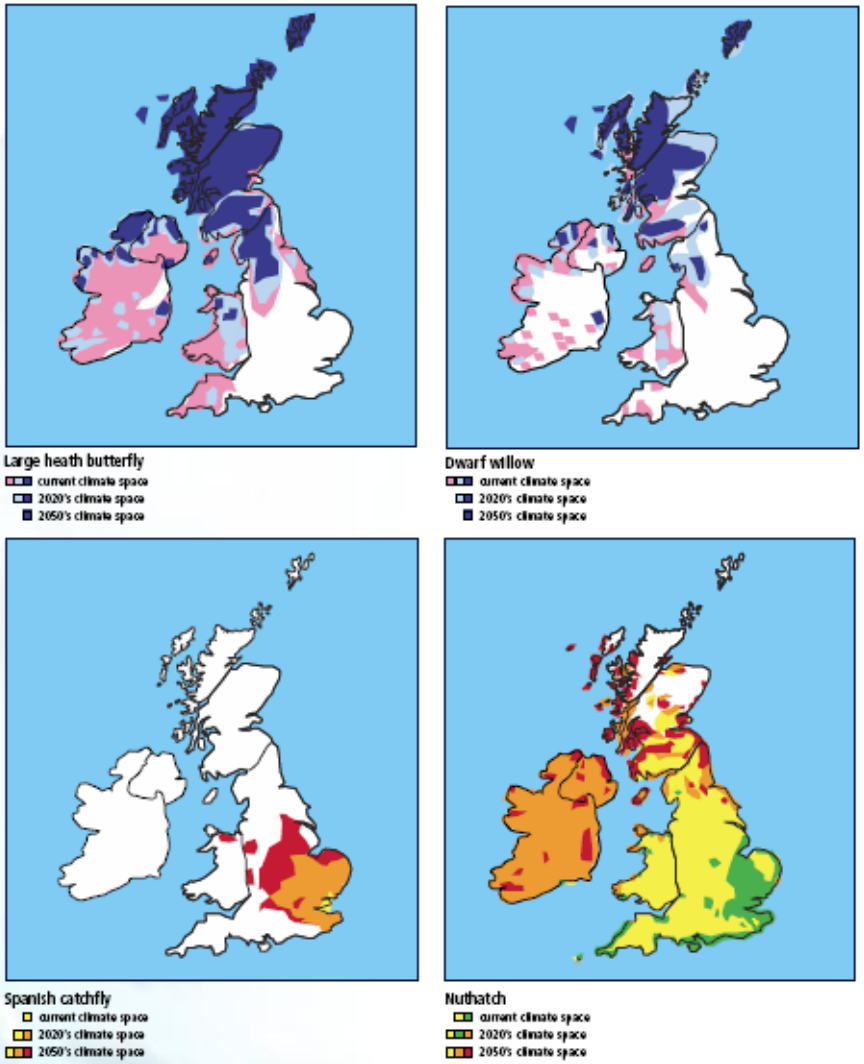
- Actual range shifts may not occur if distributions are linked to other factors such as light/daylength

- Species are expected to follow the climate and change their distribution – but this depends on ability to disperse (move) and availability of resources in new areas


UK Climate Impacts Programme
Climate Change and Nature Conservation in Britain and Ireland
MONARCH - Modelling Natural Resource Responses to Climate Change
Summary Report

Present and future climate space, based on the UKCIP 98 High scenarios for 2020s and 2050s.

These diagrams show two species, the large heath butterfly and dwarf willow, that are potential losers of climate space and two that could gain climate space, the Spanish catchfly and the nuthatch.



Habitat fragmentation and natural barriers (such as the sea) will limit the capacity of some species to disperse

http://www.eci.ox.ac.uk/research/biodiversity/downloads/Monarch3synthesis.pdf

Climate envelope modelling

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Climate Envelope Modeling for Threatened and Endangered Species

Climate change is creating new challenges for biodiversity conservation. As temperatures, rainfall patterns, and sea levels change, distributions of plants and animals may shift geographically, altering their relationships with the environment and other species. As part of the response to climate change, the conservation community is starting to make decisions on longer time frames and with a focus on "adaptation" strategies to help species and habitats adjust. One of the first steps in adaptation planning is to conduct vulnerability assessments to identify which species or systems are likely to be most affected by climate change and why.

Climate envelope models are an important tool used in vulnerability assessments to help resource managers understand how plants and animals may respond to a changing climate. Climate envelope models describe the climate where a species currently lives (its climate "envelope"), and then map the geographic shift of that envelope under climate change. Because we can't know for certain how climate will change in the future, multiple climate change scenarios are used in these models.

Go to map

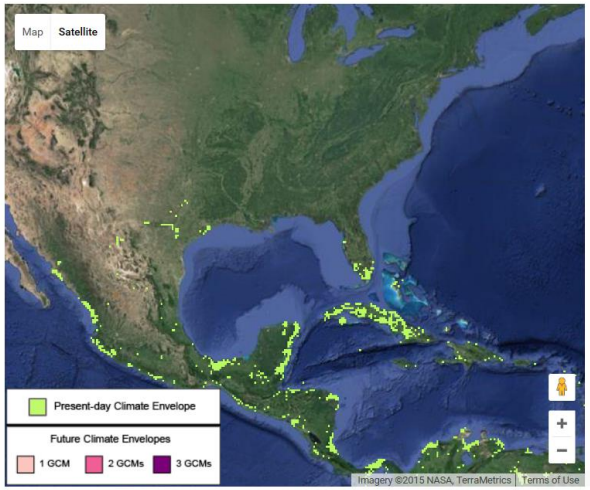
Our future work will incorporate habitat data and other kinds of information into the models to refine projections for future distributions of threatened and endangered species. Well-validated models can provide information for natural resource planning by identifying species most at risk from climate change and highlighting areas of potential future conflict between human activities and conservation priorities. The climate envelope modeling project is a partnership among the University of Florida, U.S. Fish and Wildlife Service, U.S. Geological Survey, and National Park Service.

http://crocdoc.ifas.ufl.edu/projects/climateenvelopemodeling/

Climate envelope modelling

***Remember**: The future climate envelope represents where a species may occur based on climate factors alone. That is, these maps do not consider the types of habitats, topography, or food sources each species needs to survive. For example, we would not expect American crocodiles, a coastal species, to turn up in the Midwest. Thus, these models serve best as initial screening tools to identify priority areas for further study.*

American Crocodile ◉ Present-day climate envelope ○ 2060 climate envelope ○ 2100 climate envelope



American Crocodile

Crocodylus acutus

Photo credit: Jemeema Carrigan

Federal Status: Threatened

Florida Status: Threatened

Distribution: Coastal areas of Mexico, Central and South America, the Caribbean, and south Florida. In Florida crocodiles are restricted to the southern coast of the Everglades, northern Florida Keys, and Biscayne Bay.

Habitat: Mangrove swamps, coastal rivers and estuaries, and human-made canals and ponds. Nesting habitat (beaches and creek banks) must be elevated, protected and near

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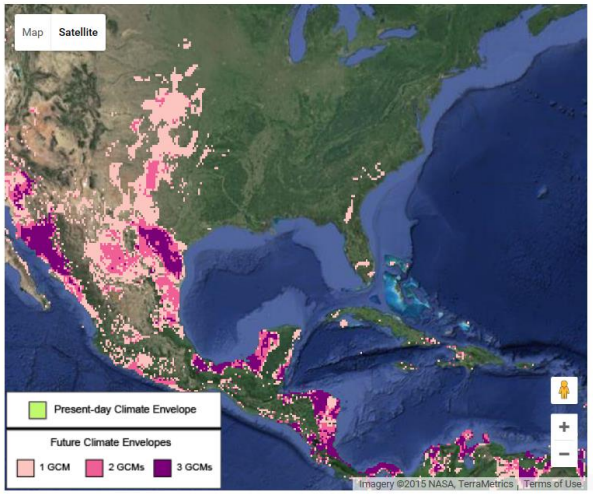

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Bioclimatic envelopes have been criticised

- Because they assume that climate alone determines species distribution
- They appear to imply that under future scenarios an equilibrium with climate will be reached very quickly
- Probably indicate maximum future potential distribution
- Other factors are habitat availability, local extinctions, colonisation dynamics and dispersal

Actual range shifts

Species	Location	Changes
Tree line	Europe, New Zealand	Advance towards higher latitudes
Arctic shrubs	Alaska	Expansion in previously shrub-free areas
Zooplankton, intertidal invertebrate and fish communities	Californian coast, north Atlantic	Increasing abundance of warm water species
Butterfly species,	North America, Europe	Northward range shifts up to 200 km over 27 years
12 bird species	Britain	19 km average range movement north over 20 years
Red fox, Arctic fox	Canada	Northward expansion of red fox range and retreat of arctic fox range

http://www.nhm.ac.uk/visit/wpy/gallery/2015/images/mammals/4965/a-tale-of-two-foxes.html

Source: Walther et al., 2002

Climate change on coral reefs

- Coral reefs appear to be very vulnerable ecosystems
- Seem to be located near their upper thermal limits so that are susceptible to ‘relatively small’ increases in temperature
- Warmer water temperatures can result in coral bleaching
- Bleaching - corals will expel the algae (zooxanthellae) living in their tissues causing the coral to turn completely white.
- When a coral bleaches, it is not dead. Corals can survive a bleaching event, but they are under more stress and may die if stressed further.

http://www.publish.csiro.au/?act=view_file&file_id=MF99078.pdf

Climate change on coral reefs

- 6 periods of mass coral bleaching occurred since 1979 and incidence increasing in frequency and intensity
- In 1998, estimated 16% of world's reef building corals died
- Likely to lead to large changes in ecosystem species richness and community structure

Climate change on coral reefs

- https://www.youtube.com/watch?v=526n0WhyJGQ

There are other contributory factors e.g. pollution

CNBC

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Sunscreen ingredient may be killing off coral reefs: Study

Researchers find that oxybenzone is toxic to coral even at extremely low concentrations of 65 parts per trillion, equal to the ratio of a single drop to 6½ Olympic-size swimming pools.

Robert Ferris | @RobertoFerris

Thursday, 22 Oct 2015 | 1:30 PM ET

CNBC

A common sunscreen ingredient may be contributing to the deaths of coral reefs around the world, according to a new study.

Antarctic ecosystems

Antarctic ecosystems

- Simple communities compared with coral reefs
- Colonisation of bare ground by mosses, expansion of the numbers and spread of the only two higher plants present, colonisation by soil invertebrates
- Increasing temperatures mean less likely that organisms will be exposed to lower thermal limits – allowing development of species previously at the edge of their range
- In a few cases species are near their upper thermal limits

Alien species

- Non-indigenous species that have arrived in a new location, often through human intervention. Humans are probably the MOST INVASIVE species!
- Species have always moved, but globalisation and other factors are increasing invasion rates.
- Can be animals, plants, microbes.
- **Can you think of some examples?**

Why do alien species cause problems?

- Often have negative impact on biodiversity
- More homogeneous, less diverse and less stable biotas
- Often become ‘pests’ - either on crops or because of environmental/physical damage
- May out-compete or kill native species
- Invasive plants may block watercourses or increase fire risk in e.g. Australia

Three stages of invasion

- Arrival – transportation to new areas
- Establishment – formation of a self-sustaining population in a new area
- Spread – expansion to suitable habitats and interaction with surrounding ecosystem

H. Vanhanen – Academic dissertation

Migrant Lepidoptera

- Increased migration of moths and butterflies to UK
- 1°C rise in temperature in south west Europe »14 new species (Sparks *et al,* 2007)
- Most from due south and fly over many km of sea
- Wind direction, especially high altitude wind, is important
- Wind likely to have strong influence on pests - on arrival of immigrants (and timing of arrival) and eventual spread
- Climate change models do not contain robust wind component

Establishment and spread

- Establishment depends on:
  - Climate/weather
  - Availability of suitable habitat and hosts
  - Low mortality – abiotic and biotic factors
- Spread depends on:
  - Natural dispersal
  - Dispersal of host plants/vectors
  - Climate/weather
- A number of suggestions about how to predict invasiveness……..

Phytophthora ramorum – sudden oak death

Phytophthora ramorum

- Exotic fungus-like pathogen.
- Origin unknown.
- First identified in California in 2000 and then later in Oregon, USA: in both these states it causes a highly damaging tree disease known as Sudden Oak Death.
- Same *Phytophthora* has also been found to cause a disease of rhododendrons and viburnums, which was first reported in Europe from Netherlands and Germany.

Phytophthora ramorum

- Main hosts are rhododendron and viburnum, but other genera can be hosts, including *Camellia*, *Kalmia*, *Pieris*, *Hamamelis* and *Syringa.*

- Has also been recorded once on small pot-grown yew plants (*Taxus baccata*) growing close to infected viburnums in a UK nursery.

- First record of *P. ramorum* on a mature tree outside USA occurred in UK in November 2003.

Gary Chastagner
Washington State University

Symptoms Vary by Host

Most hosts are not killed

Leaf spot

Shoot dieback

Cankers/mortality

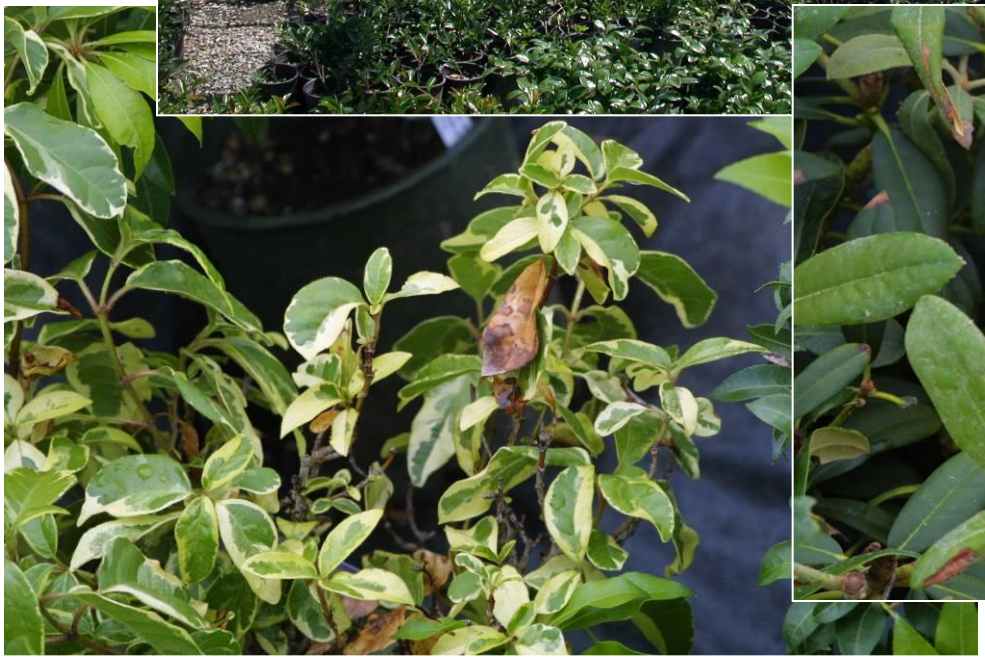
- Sudden Oak Death - bleeding cankers on trunks of trees that results in mortality of tree
- Ramorum Blight or Dieback – Leaf spots, twig cankers and dieback

Phytophthora ramorum

- Spread is aerial, probably in rain splash, mist-laden winds or via watercourses.

- In UK, infected trees have been found in close proximity to heavily infected rhododendrons, which probably act as main source of spores of *P. ramorum*.

Spread of *P. ramorum* via Shipment of Infected Nursery Stock



Phytophthora and climate change

Climate change will affect

1. Pathogen
2. Host
3. Pathogen x host interaction

- Least known about interaction - but often little information on possible response of pathogen as well. So modelling/prediction can be difficult.

- Climate change will also affect local ecosystem

Activity of *Phytophthora cinnamomi* in Europe as predicted by a computer model. Size of dot indicates relative activity.

Infects chestnut, oaks and other species.

Activity under late 1990s conditions.

Activity assuming a 3°C increase in mean annual temperature (a current climate change prediction for circa 2100).

http://www.apsnet.org/online/proceedings/sod/Papers/Brasier/default.htm

Phytophthora and climate change

- Climate change is likely to be broadly detrimental to tree health and favour some highly damaging pathogens

- Host x pathogen systems involving non-native hosts and invasive pathogens are likely to be at highest risk, a further argument for more effective controls to prevent arrival of invasive pathogens

- There is a case for planting native trees and encouraging native ecosystems assuming these are better ecologically buffered and may have a wider gene pool for host adaptation

Clive Brasier, Forest Research

Effect of climate change on species interactions

- Responses by individual species to climate change may disrupt interactions with others.

- Climate change is affecting the reproductive grounds of krill (food for birds, whales, seals) by reducing area of sea ice formed near the Antarctic Peninsula – leads to consequence for the food web.

- Also indirect effects from behaviour of North Atlantic Oscillation. Affected availability of plankton food for fish larvae which determines size of fish populations

Effect of climate change on species interactions

- In Britain, newts are entering ponds earlier than before whereas frogs haven't changed their phenology much. This leads to higher levels of predation on frog eggs and tadpoles by newts.

- Warmer spring weather in Europe has disrupted synchrony between winter moth hatching and oak bud burst, leading to a mismatch in caterpillar availability and peak food demands of young Great Tits.

©John Beniston

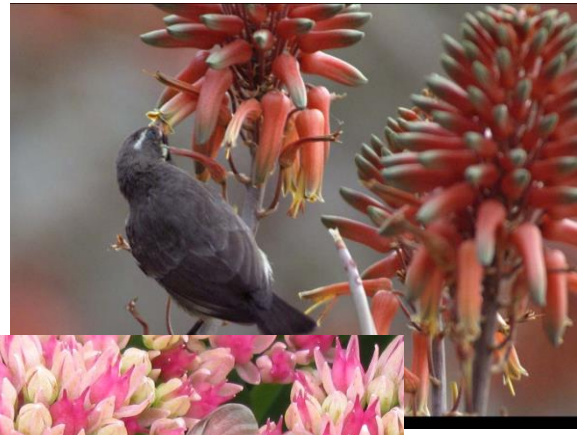
©Francis C Franklin

Pollination

- Pollinators include bees, butterflies, birds, moths, flies, beetles, bats

- Said that 15-30% US diet is result of animal-mediated pollination – but estimate probably on the high side

- Fruit, nuts, vegetables, oils and meat/dairy from animals fed on insect-pollinated forage



Phenology of pollinators and plants

- Modelled interactions between 1420 pollinator and 429 plant species to simulate consequences of phenological shifts expected with a doubling of atmospheric CO_2.

- Depending on model assumptions, phenological shifts reduced floral resources available to 17–50% of all pollinator species, causing as much as half of the ancestral activity period of the animals to fall at times when no food plants were available.

- Reduced overlap between plants and pollinators also decreased diet breadth of pollinators.

- Predicted result is extinction of pollinators, plants and their interactions.

Ecology Letters, (2009) **12**: 184–195 doi: 10.1111/j.1461-0248.2008.01269.x

REVIEW AND SYNTHESES

How does climate warming affect plant-pollinator interactions?

Stein Joar Hegland[1], Anders Nielsen[1,2], Amparo Lázaro[1], Anne-Line Bjerknes[1] and Ørjan Totland[1]

Abstract

Climate warming affects the phenology, local abundance and large-scale distribution of plants and pollinators. Despite this, there is still limited knowledge of how elevated temperatures affect plant-pollinator mutualisms and how changed availability of mutualistic partners influences the persistence of interacting species. Here we review

Phenology of pollinators and plants

- Global warming could disrupt timing of pollination in alpine environments, with serious negative impacts to both plants and pollinators
- High altitudes are one of the habitats where it seems that climate change is having dramatic effects
- Timing of flowering has become earlier, abundance of some flowers has changed, and synchrony of plants and pollinators may be changing
- Earthwatch Institute. "Climate Change Threatens Pollination Timing." ScienceDaily http://www.sciencedaily.com/releases/2006/08/060809234056.htm

Managed ecosystems

- A large proportion of the earth's surface is managed for forestry and agriculture to provide humans with fuel, fibre and fuel

- Managed land often has a 'simpler' ecosystem partly because plant species diversity is less – but there are still significant impacts from climate change on the plants (crops and weeds), livestock and their pests and diseases

Impacts of climate change

- **Crops**
  - Too little water (irrigation?), too much water
  - CO_2 concentration
  - Weeds, pests and disease
- **Livestock**
  - Need for fodder – as for crops
  - Pests and disease
- **Forestry**
  - Water, pests and disease

What are we doing?

- Studies to determine the impact of climate change on crops, livestock, weeds, pest, diseases

- Sometimes using mathematical models which may have been developed for other reasons initially

Wheat bulb fly

- Young and Cochrane (1993) devised forecasting model derived empirically from field sampling in East Anglia 1952 – 1990.
- Relationships were derived by stepwise regression analysis.

model forecasts % of fields with > 2.5 million eggs per ha

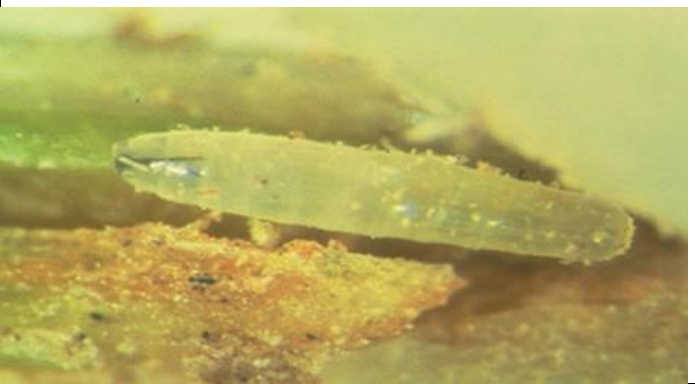
Ang(%) = 36.9 – (4.25 X JyTT) – (0.0609 X OcRR) + (0.671 X AuRd)

Where

JyTT = departure from average of July air temperatures

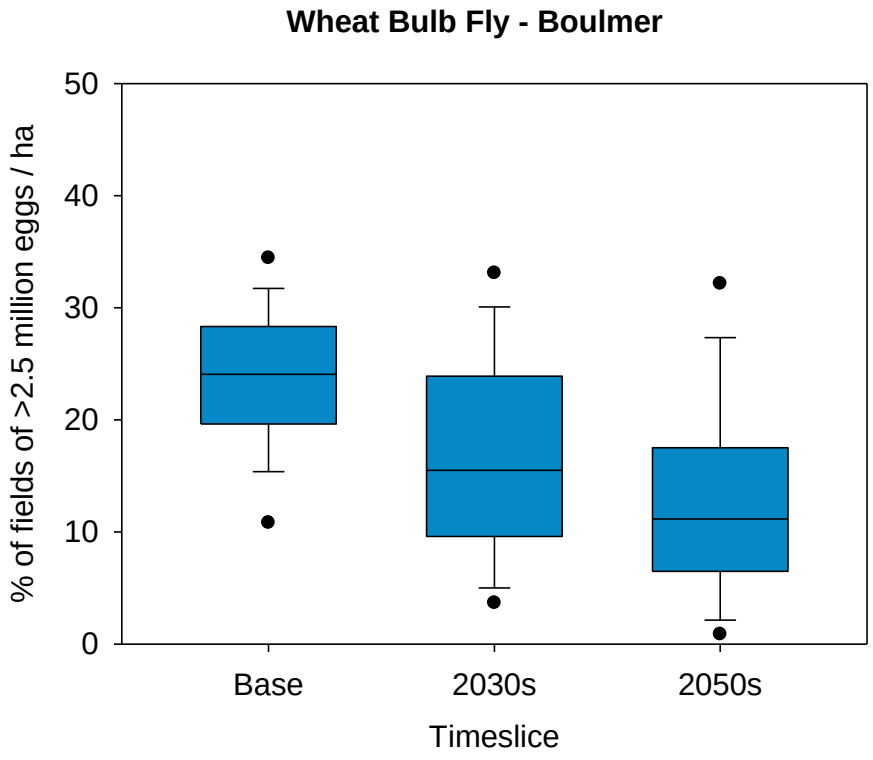
OcRR = percentage of average rainfall in October of previous year

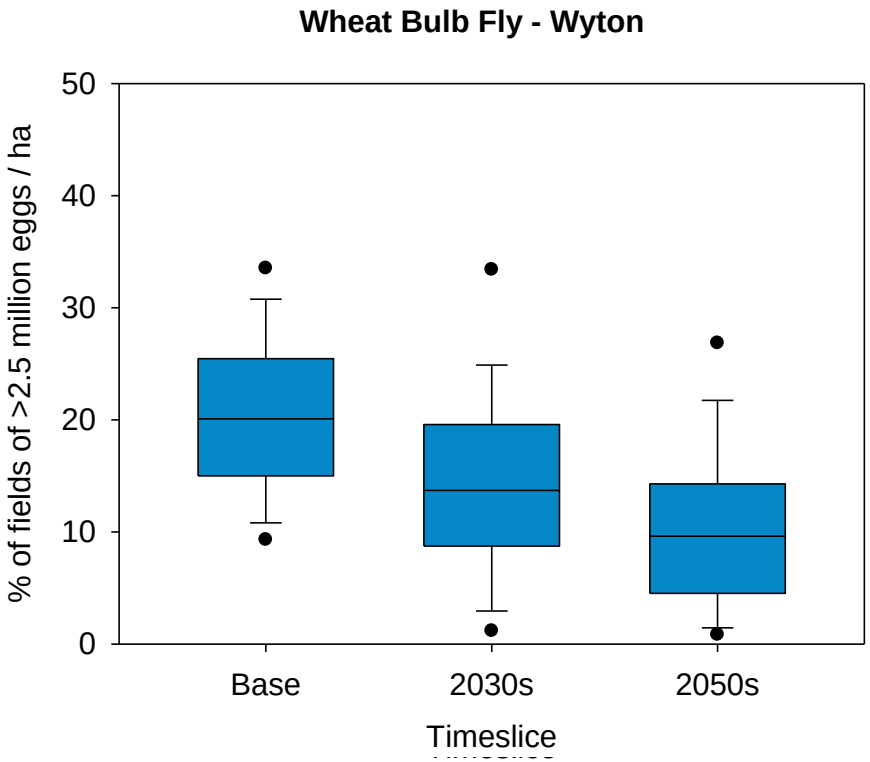
AuRd = departure from average of August rain days



Lays eggs in exposed soil in July-August. Eggs hatch January-March. Larvae bore into base of cereal plants feeding on central shoot.

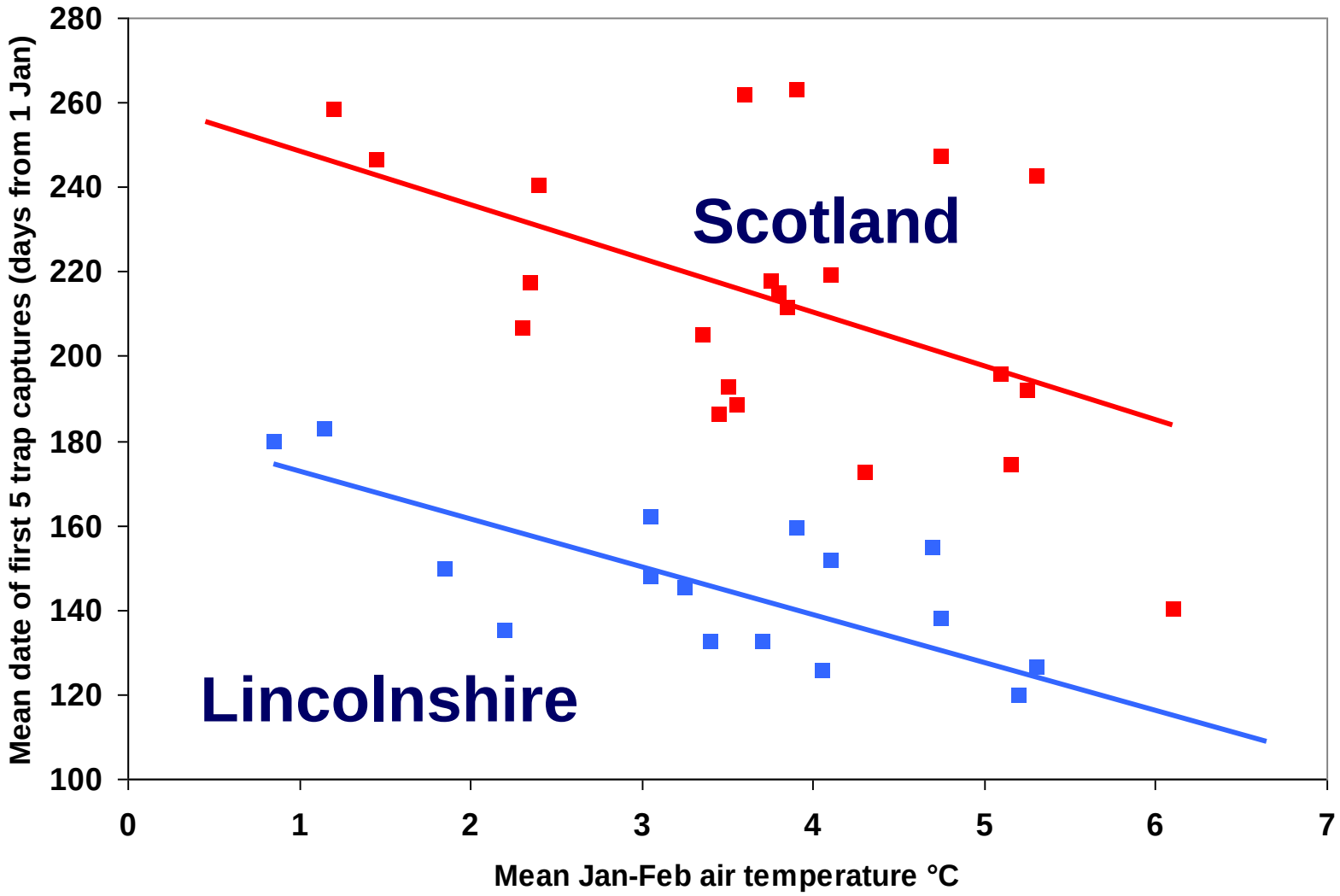
Percentage of fields with > 2.5 million eggs per ha





Myzus persicae

Date when first aphids captured versus winter temperature – Rothamsted suction traps



Myzus persicae

First aphid migration predicted using following equation (Collier & Harrington 2001).

$$D = 256.6 - 11.616\ JFT + 4.44\ JFR - 44.78\ X - 9.65\ Y + 4.304\ X^2 + 0.947\ Y^2 + 2.308\ XY + 0.1353\ Z$$

D - date of first record expressed as 1 = 1 January

JFT - mean temperature in January and February (^oC)

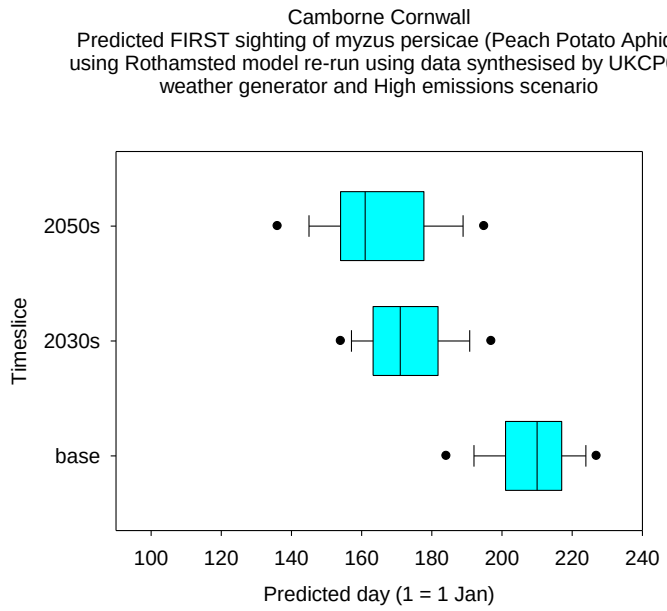
JFR -total rainfall in January and February (log_e mm)

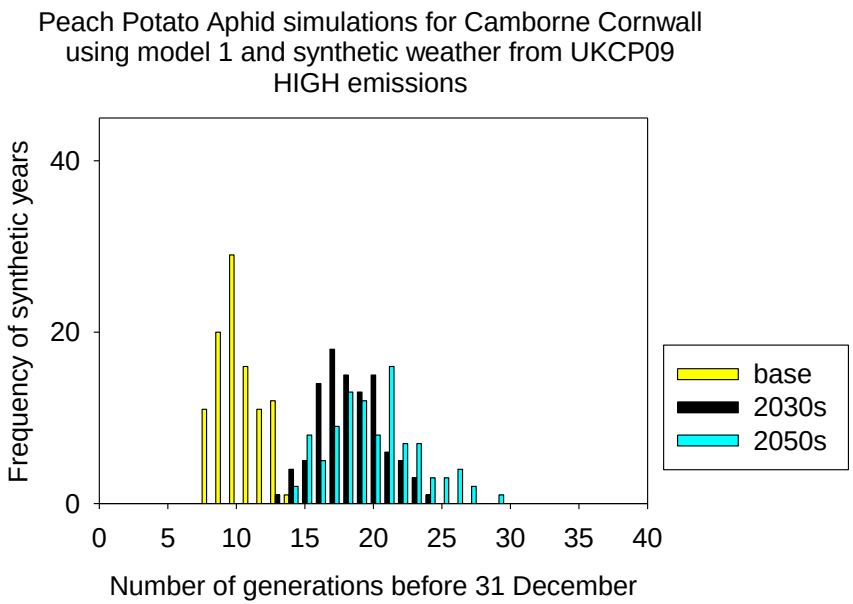
X - longitude (as four figure grid reference / 1000)

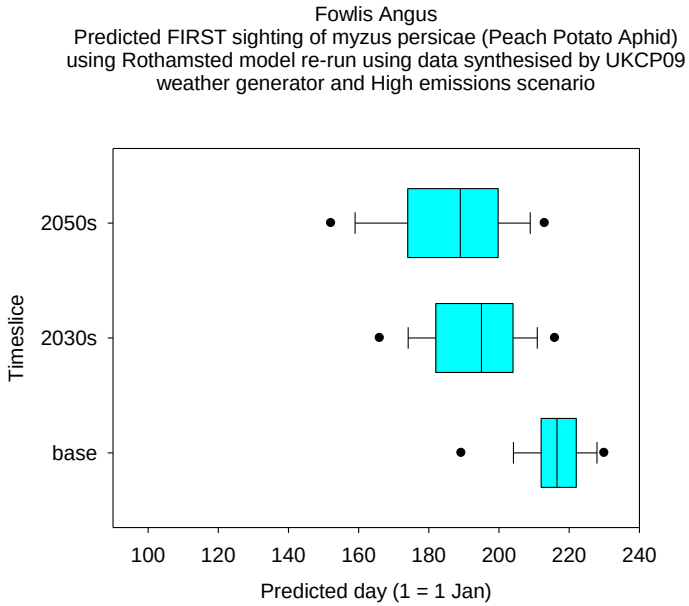
Y - latitude (as four figure grid reference / 1000)

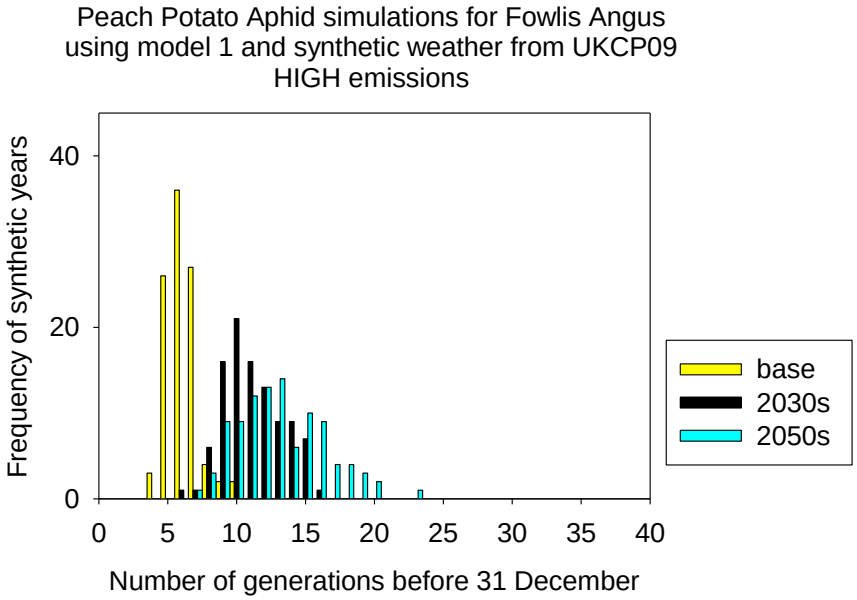
Z - altitude

Model of Whalon & Smilowitz (1979) predicts generation time from nymph to nymph using day-degree sum with base temperature of 4 ^oC and upper limit of 30^oC.


Camborne Cornwall
Predicted FIRST sighting of myzus persicae (Peach Potato Aphid)
using Rothamsted model re-run using data synthesised by UKCP09
weather generator and High emissions scenario
Timeslice
2050s
2030s
base
100
120
140
160
180
200
220
240
Predicted day (1 = 1 Jan)


Peach Potato Aphid simulations for Camborne Cornwall
using model 1 and synthetic weather from UKCP09
HIGH emissions
Frequency of synthetic years
0
20
40
0
5
10
15
20
25
30
35
40
Number of generations before 31 December
base
2030s
2050s


Fowlis Angus
Predicted FIRST sighting of myzus persicae (Peach Potato Aphid)
using Rothamsted model re-run using data synthesised by UKCP09
weather generator and High emissions scenario
Timeslice
2050s
2030s
base
100
120
140
160
180
200
220
240
Predicted day (1 = 1 Jan)


Peach Potato Aphid simulations for Fowlis Angus
using model 1 and synthetic weather from UKCP09
HIGH emissions
Frequency of synthetic years
0
20
40
0
5
10
15
20
25
30
35
40
Number of generations before 31 December
base
2030s
2050s

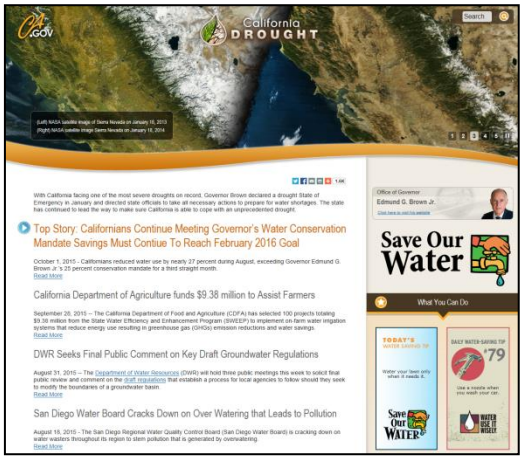
Implications of climate change

- Water shortages
- Change in crops grown or livestock kept
- Soil degradation, soil erosion, salinisation
- Impacts on food security

What are we doing?

- Identifying approaches for mitigation of climate change – agriculture contributes significantly to greenhouse gas emissions

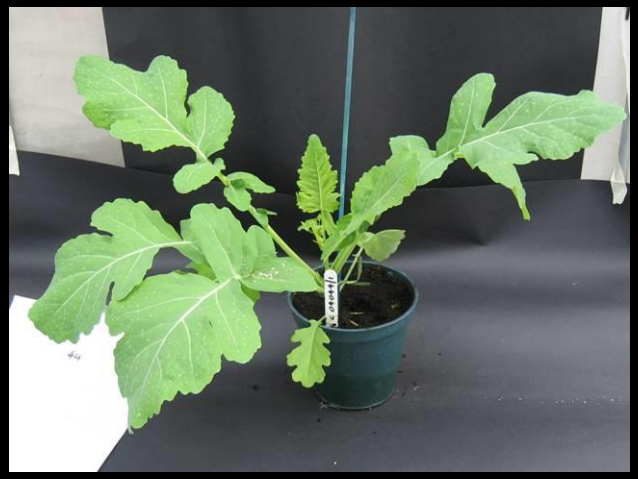
- Identifying approaches for adaptation
  - Improved water use efficiency
  - Better soil management
  - Crop breeding



Breeding for crops and livestock that do better in changed conditions

- Crops
  - Water use efficiency
  - Pest and disease resistance
  - Nutrient use efficiency
  - Sources of resistance (genes in old varieties of crops and crop wild relatives)
  - We are doing this in Life Sciences at Warwick which also hosts UK Vegetable Gene Bank

Wild *Brassica* species



Additional information

- http://www3.epa.gov/climatechange/Downloads/Climate_Change_Ecosystems.pdf

- http://www.uvm.edu/~bbeckage/Teaching/HCOL_185_2014/AssignedPapers/Walther.Nature.2002.pdf

review article

Ecological responses to recent climate change

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Seminar – 5th November

- We will discuss some of the other factors that put pressure on ecosystems – bring at least two examples to discuss.
- We will discuss the concept of ecosystem services.
- How can we reduce the pressure on ecosystems and how would it be regulated/financed? Bring at least one example to discuss.