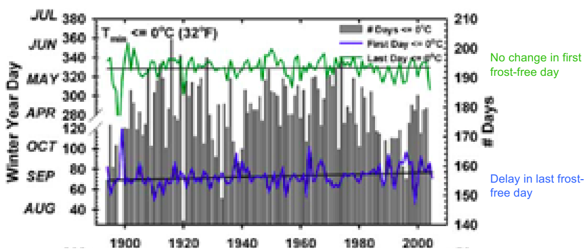
Section 4: Phenology

Learning outcomes

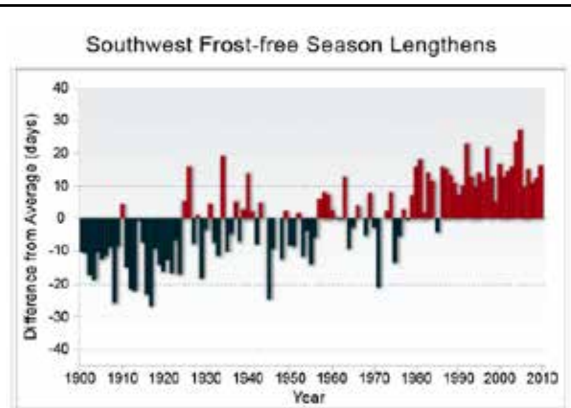
- understand what phenology is and what mechanisms are involved
- give examples of how climate change has affected phenology in species
- explain how changes in phenology affect species interactions

Changes in climate that affect phenology

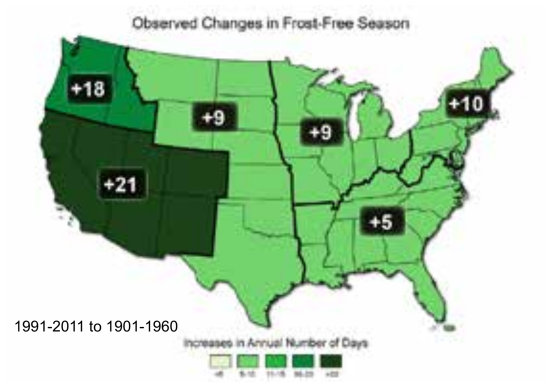
Western Montana



Pederson et al. 2010



National Climate Assessment Draft Report, 2013



National Climate Assessment Draft Report, 2013

Climate Change Ecology 4 Prof. J. Hicke

Changes in climate that affect phenology

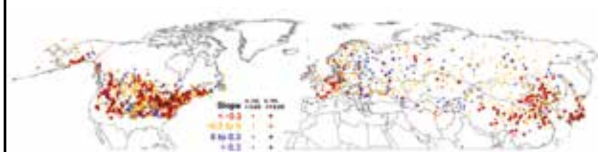
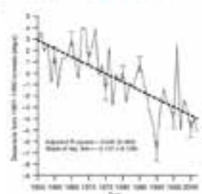


Fig. 3 Last spring −2.2 °C freeze date 1961–2000 trend by station. Details as in Fig. 1.

Last spring freeze date trend



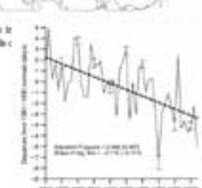
Schwartz et al., Global Change Biology, 2006

Climate Change Ecology 5

Changes in climate that affect phenology

Fig. 1 Spring indices (SI) first leaf date 1961–2000 trend by station. Trend values are i
Stations with trends significant at the 0.05 level or better are shown with larger symbols (

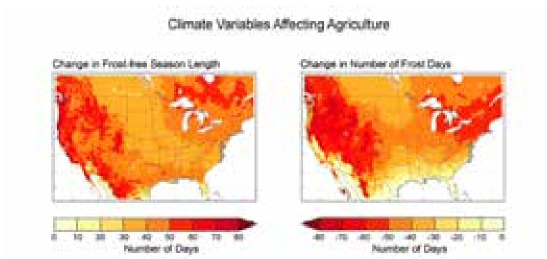
Modeled first leaf date trend



Schwartz et al., Global Change Biology, 2006

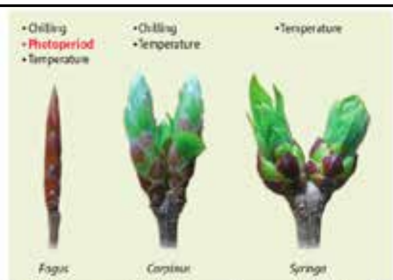
Climate Change Ecology 6

Projected changes in 2100 under A2 scenario



National Climate Assessment Draft Report, 2013

Climate Change Ecology 7 Prof. J. Hicke



Not just temperature. Spring development in many ornamental plants from warm regions, such as lilac (*Syringa*), is primarily controlled by temperature, whereas early successional species native to temperate latitudes, such as hornbeam (*Carpinus*), only become temperature-sensitive once their chilling demand has been fulfilled. Late successional taxa, such as beech (*Fagus*), are photoperiod controlled, with temperature only exerting a limited modulating effect once the critical day length has passed. This mechanism prevents such taxa from sprouting at the "wrong" time.

Körner and Basler, Science, 2010

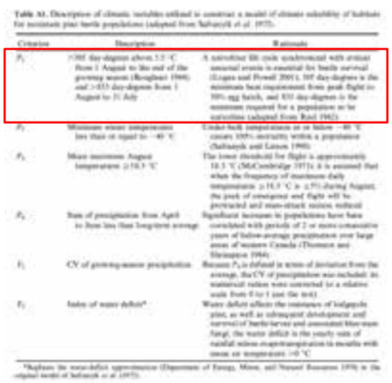
Climate Change Ecology 8 Prof. J. Hicke

Plant development

Common name	Latin name	Number of growing degree days baseline 10 °C
Witch-hazel	Hamamelis spp.	begins flowering at <1 GDD
Red maple	Acer rubrum	begins flowering at 1-27 GDD
Forsythia	Forsythia spp.	begin flowering at 1-27 GDD
Sugar maple	Acer saccharum	begin flowering at 1-27 GDD
Norway maple	Acer platanoides	begins flowering at 30-50 GDD
White ash	Fraxinus americana	begins flowering at 30-50 GDD
Crabapple	Malus spp.	begins flowering at 50-80 GDD
Common Broom	Cytisus scoparius	begins flowering at 50-80 GDD
Horsechestnut	Aesculus hippocastanum	begin flowering at 80-110 GDD
Common lilac	Syringa vulgaris	begin flowering at 80-110 GDD
Beach plum	Prunus maritima	full bloom at 80-110 GDD
Black locust	Robinia pseudoacacia	begins flowering at 140-180 GDD
Catalpa	Catalpa speciosa	begins flowering at 250-330 GDD
Privet	Ligustrum spp.	begins flowering at 330-400 GDD
Elderberry	Sambucus canadensis	begins flowering at 330-400 GDD
Purple loosestrife	Lythrum salicaria	begins flowering at 400-450 GDD
Sumac	Rhus typhina	begins flowering at 450-500 GDD
Butterfly bush	Buddleia davidii	begins flowering at 500-650 GDD
Corn (maize)	Zea mays	2700 GDD to crop maturity
Dry beans	Phaseolus vulgaris	1100-1300 GDD to maturity depending on cultivar and soil conditions
Sugar Beet	Beta vulgaris	130 GDD to emergence and 1400-1600 GDD to maturity
Barley	Hordeum vulgare	125-160 GDD to emergence and 1290-1540 GDD to maturity
Wheat (Hard Red)	Triticum aestivum	143-176 GDD to emergence and 1550-1680 GDD to maturity
Oats	Avena sativa	1500-1750 GDD to maturity
European Corn Borer	Ostrinia nubilalis	207 - Emergence of first spring moths

en.wikipedia.org/wiki/Growing-degree_day

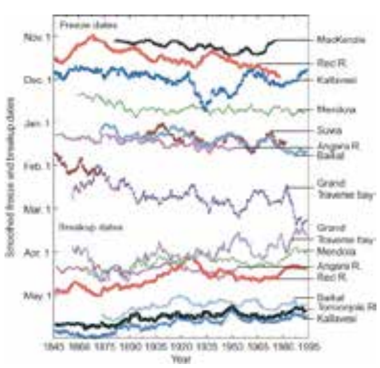
Prof. J. Hicke



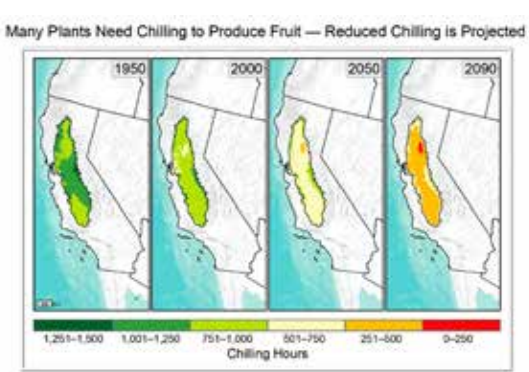
Climate factors that influence bark beetles

Safranyik et al., 2010

Changes in ice formation, breakup

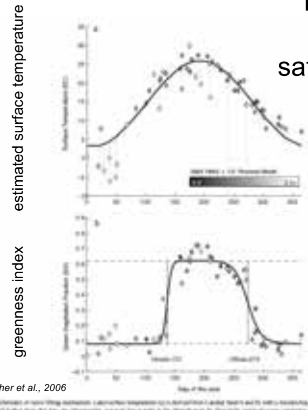


What are the implications for plants, animals?



National Climate Assessment Draft Report, 2013

Defining vegetation phenology using satellite remote sensing

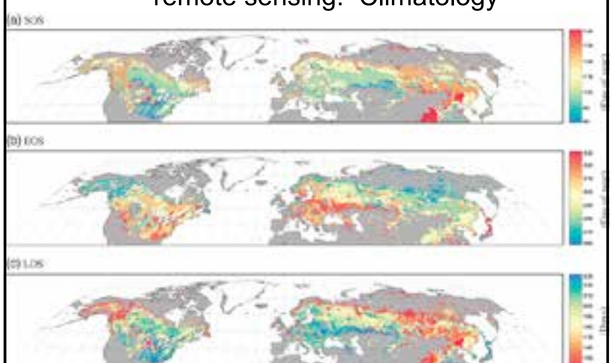


T used to identify outliers that are then weighted less

Fischer et al., 2006

Prof. J. Hicke

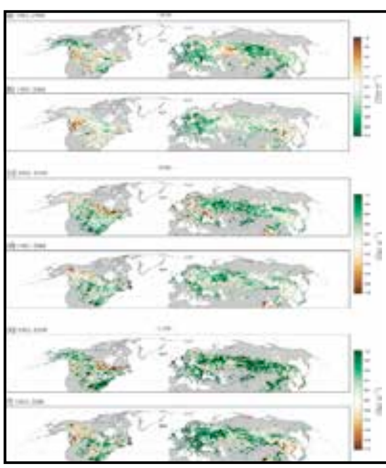
Defining vegetation phenology using satellite remote sensing: Climatology



Climate Change Ecolc *Jeong et al., GCB, 2011* Prof. J. Hicke

Defining vegetation phenology using satellite remote sensing:

Trends in last decades

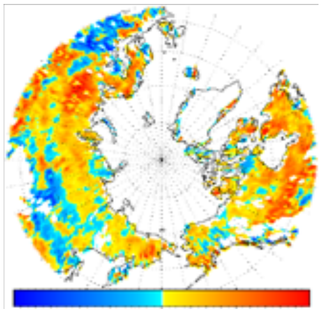


Jeong et al., GCB, 2011

Prof. J. Hicke

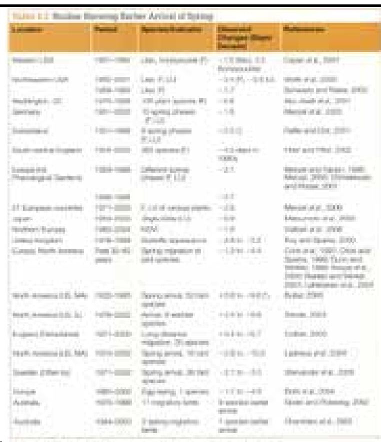
Satellite-derived increases in growing season length

1982-2005



Smith-Downey et al., 2006

Climate Change Ecology 16 Prof. J. Hicke



Hannah 2011

Climate Change Ecology Prof. J. Hicke

Meta-analysis of spring phenology

1. almost all are advances
2. consistent changes across taxa

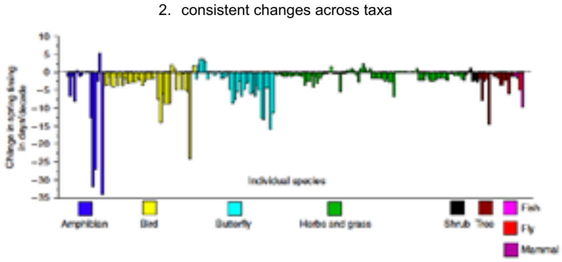


Fig. 2 Changes in timing of spring events in days/decade^{-1} for individual species grouped by taxonomy or functional type for the combined dataset. Each bar represents a separate, independent species. Negative values indicate advancement (earlier phenology through time) while positive values indicate delay (later phenology through time).

Parmesan, 2007

Climate Change Ecology 18 Prof. J. Hicke

Spring warming => biological responses

Later

Earlier

Colder

Warmer

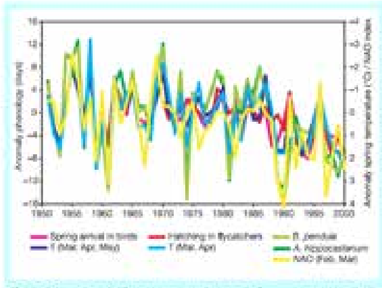


Figure 2 Anomalies of different phenological phases in Germany correlate well with anomalies of mean spring air temperature *T* and NAO index (by P. D. Jones, http://www.cru.uea.ac.uk/cru/data/nao.htm). Temperature taken from 35 German climate stations. Phenological phases used: spring arrival in birds, Island of Helgoland, North Sea; hatching in flycatchers (*Ficedula hypoleuca*), Northern Germany; and mean onset of leaf unfolding of *Aesculus hippocastanum* and *Betula pendula*.

Walther et al., 2002

Warming and laying date

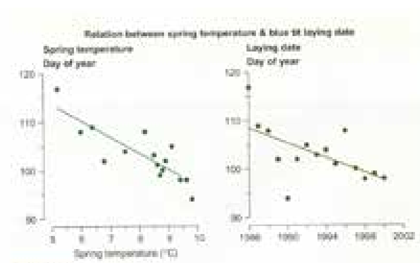
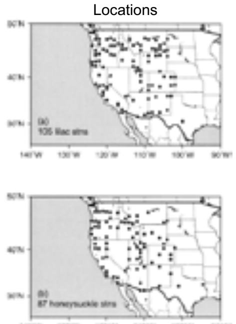


FIGURE 4.5

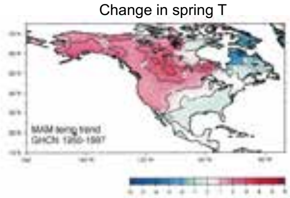
Hannah 2011

Lilac and honeysuckle first bloom dates

Locations



Change in spring T



Cayan et al., Bulletin of Amer. Met. Soc., 2001

Lilac and honeysuckle first bloom dates

Spring warming, earlier runoff, earlier blooming

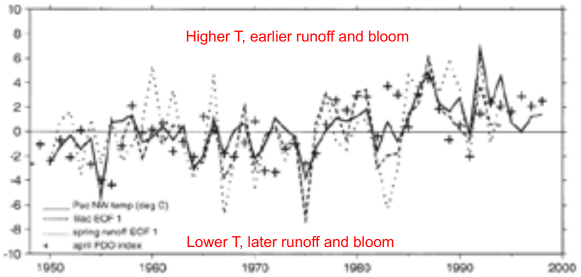


FIG. 13. Time history of spring (Mar–May) temperature anomalies (solid, °C) averaged over the interior northwestern United States, EOF 1 of lilac first bloom date anomalies (dashes), and EOF 1 of runoff spring pulse date anomalies (dots). Apr PDO (crosses) is also shown. Temperature is the average of eastern Washington, Idaho, western Montana, and western Wyoming divisional values.

Cayan et al., Bulletin of Amer. Met. Soc., 2001

Lilac and honeysuckle first bloom dates

Analysis of lilac first bloom dates in Spokane

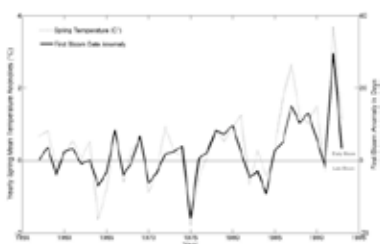
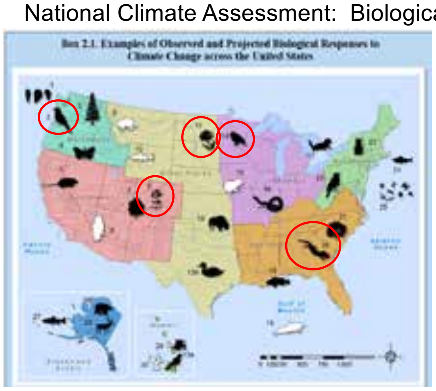


Figure from V. Jansen, UI, climateinw.wordpress.com/2012/05/29/the-lilac-city-and-spring-phenology/

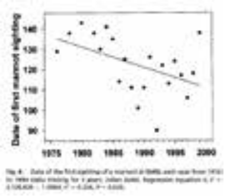
National Climate Assessment: Biological Responses

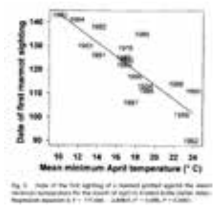


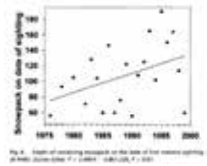
2. N. Flickers arrive earlier, lay eggs earlier due to warming
8. RM high-elevation areas: Flower phenology changes; declines in flower resources that may affect pollinators; earlier growth led to higher susceptibility to frost; decoupling plant/pollinator interactions with earlier plant phenology compared with insects; all due to warming
11. Earlier first flowering dates in 40% of 178 plant species examined; warming
14. Earlier arrival dates of 36% of 44 species of migratory birds; warming in winter
20. Arrival times of amphibians to breeding sites:
    - autumn breeders: later
    - winter breeders: earlier
    - warming nighttime T and precip

Staudinger, et al. Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment, 2012

Climate change may lead to seasonal mistiming







Consequences for marmot???

Inouye et al., 2000

Climate change may lead to seasonal mistiming

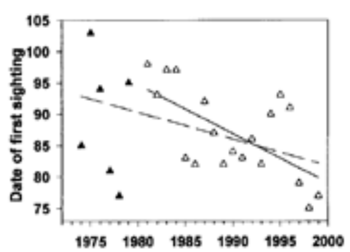
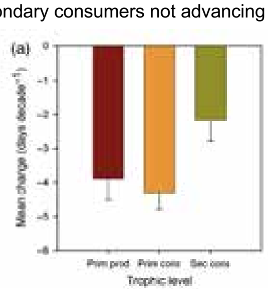


Fig. 3. Date of the first sighting of a robin at RMBL each year from 1974 to 1999 (Julian date). The two lines are regressions, including 1974–1980 (▲ and dashed line; P = 0.109) and data from 1981 to 1999 (△ and solid line; P = 0.003).

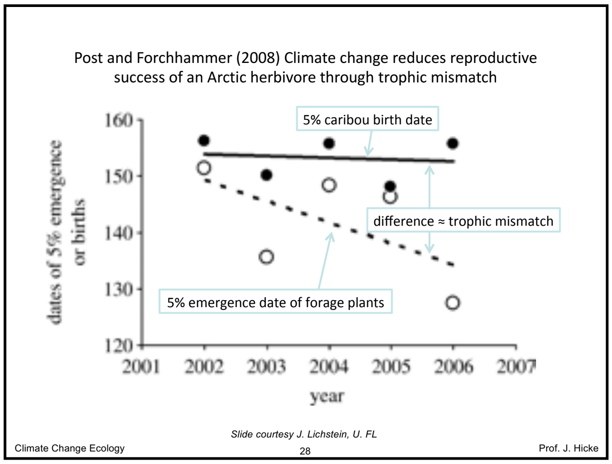
Inouye et al., 2000

Differential changes among trophic levels

Secondary consumers not advancing as quickly



Thackeray et al., GCB, 2010


Post and Forchhammer (2008) Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch
5% caribou birth date
difference ≈ trophic mismatch
5% emergence date of forage plants
dates of 5% emergence or births
160
150
140
130
120
2001
2002
2003
2004
2005
2006
2007
year
Slide courtesy J. Lichstein, U. FL
Climate Change Ecology
28
Prof. J. Hicke