Section 10-11: Tools for assessing future impacts

Reading: Hannah Ch 10-11

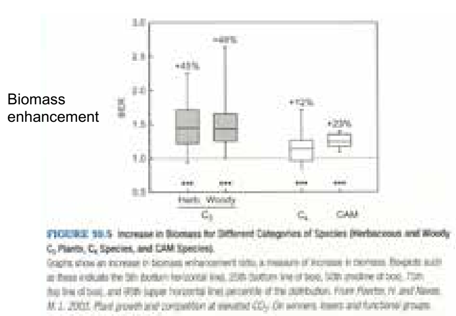
Learning outcomes

- understand and provide examples of
  - laboratory experiments
  - field experiments
  - modeling (various types)

Laboratory experiments of ↑CO2

Hannah, 2011

Effect of ↑CO2 for plants with different photosynthetic pathways



Hannah, 2011

Effect of ↑CO2 diminishes when other factors (here, competition) are present

When plants have high relative growth rate (RGR), effects of competition limit effects of CO2 fertilization

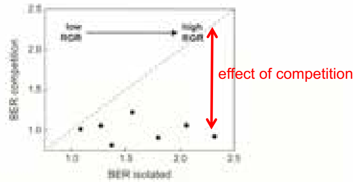


FIGURE 10.7 Biomass Enhancement for Seven Tropical Plant Species Grown in Isolation and in a Mixed Community.
The CO_2 enhancement observed in the isolated trial is not evident in the mixed community.
From Poorter, H. and Navas, M. L. 2003. Plant growth and competition at elevated CO_2: On winners, losers and functional groups. New Phytologist 157, 175–198.

Hannah, 2011

Different field experiment methods

FIGURE 10.9 Active (a) and Passive (b) Warming Experiments.
The active warming devices include the use of infrared warming lamps. Passive warming depends on blocking of air circulation or intensification of sunlight to create warmth. Passive warming devices are often simply circles or boxes of glass or clear plastic, which act much like miniature greenhouses but allow multispecies interactions and have minimal impact on received precipitation. *(a) Courtesy of Charles Must. (b) From the National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara.*

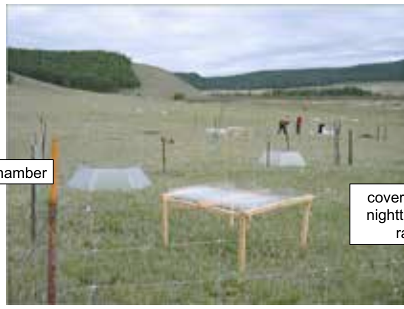
Hannah, 2011

Different field experiment methods

FIGURE 10.10 Transplantation and Open-top Chamber Experiments.
Transplantation preserves plant–plant interactions and soil properties. It is usually implemented with the movement of plants embedded in whole soil. Open-top chambers preserve plant and soil relationships over a limited area. *Source: Finnish Forest Research Institute.*

Hannah, 2011

Different field experiment methods



http://sciencespace-wang.blogspot.com/2011_06_01_archive.html

Different field experiment methods

Free air CO2 enrichment (FACE) experiments

FIGURE 10.11 Free Air CO_2 Enrichment (FACE) Experiments.
FACE experiments use massive diffusers to elevate CO_2 concentrations over a large area. Diffusers are often arrayed around a central measurement tower. (a) Courtesy of Jeffrey S. Pippen. (b) Courtesy of Professor Josef Nösberger, Swiss Face Experiment (ETH Zurich). (c) From Brookhaven National Laboratory

Hannah, 2011

Responses of ecosystem structure and function to warming among locations

Over time, the growth enhancement of ↑CO_2 diminishes

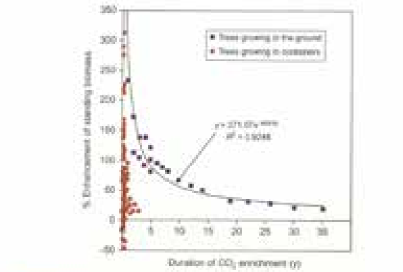
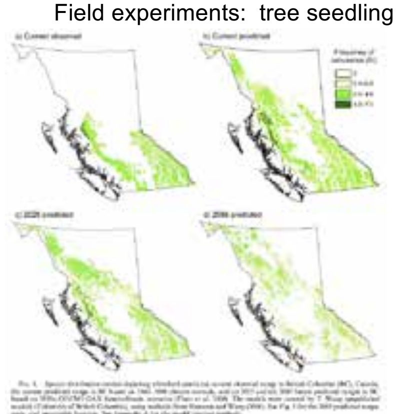


FIGURE 10.13 Acclimation in Experimental and Natural Settings. Single-plant experiments seldom span long enough time frames to detect acclimation. Whole-ground experiments, usually conducted over longer time frames, clearly show the effect of acclimation. From Idso, S. B. 1999. The long-term response of trees to atmospheric CO_2 enrichment. Global Change Biology 5, 493–495.

Hannah, 2011

Field experiments: tree seedling viability



"Whitebark pine (*Pinus albicaulis*) assisted migration potential: testing establishment north of the species range"

McLane and Aiken, Ecol. Appl., 2012

Field experiments: tree seedling viability

Trial locations (black dots)

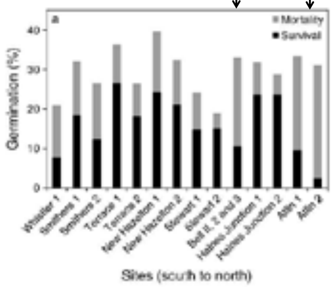
Seed sources (white squares)

McLane and Aiken, Ecol. Appl., 2012

Field experiments: tree seedling viability

Results of trials

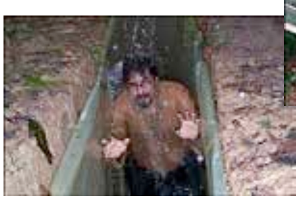
coldest sites



McLane and Aiken, Ecol. Appl., 2012

Different field experimental methods

Amazon drought experiment



http://earthobservatory.nasa.gov/Features/AmazonDrought/stealing_rain3.php, photos by D. Nepstad

(video)

Different field experimental methods

Experiment effectively reduced rainfall

treatment begins

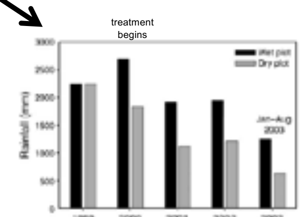
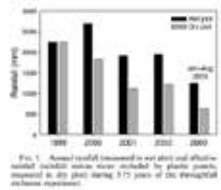
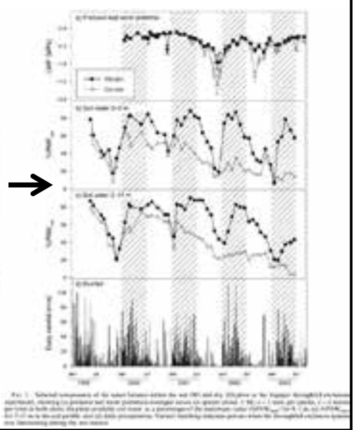


FIG. 1. Annual rainfall (measured in wet plot) and effective rainfall (rainfall minus water excluded by plastic panels; measured in dry plot) during 3.75 years of the throughfall exclusion experiment.

http://earthobservatory.nasa.gov/Features/AmazonDrought/stealing_rain3.php, photos by D. Nepstad; Nepstad et al., Ecology, 2007

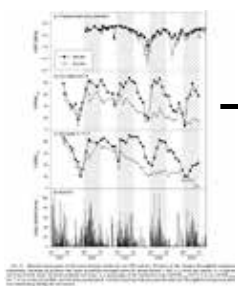
Reduced rainfall led to decreased soil moisture

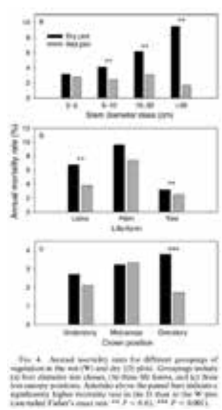




Nepstad et al., Ecology, 2007

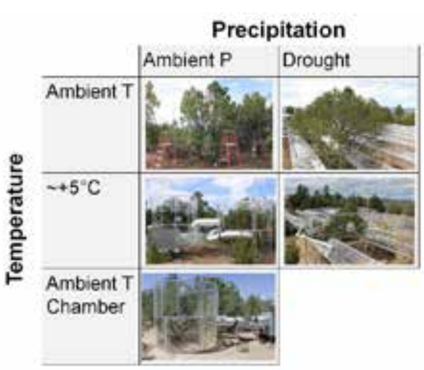
Reduced soil moisture led to plant mortality





Nepstad et al., Ecology, 2007

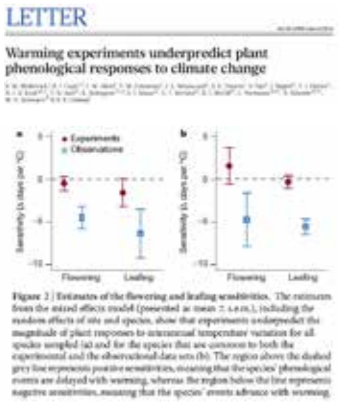
SUMO: Survival Mortality experiment in New Mexico



www.youtube.com/watch?feature=player_embedded&v=6-eyL1AlMoM

Figure courtesy N. McDowell, LANL

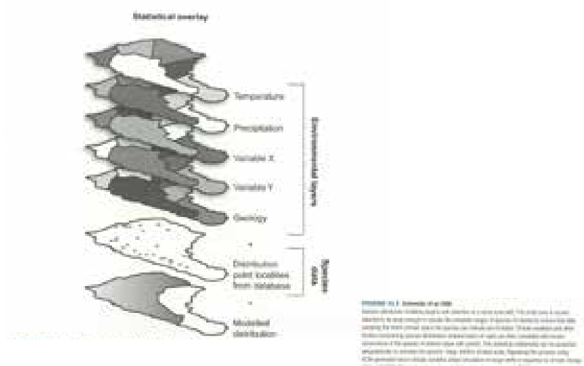
Dangers of misinterpreting experiments



Possible explanations

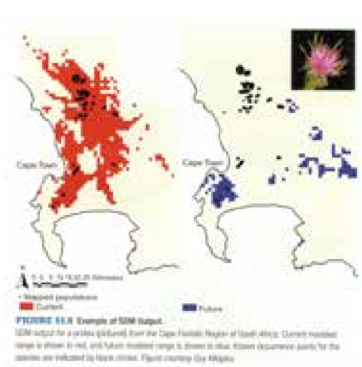
- experiments focused on T, not on correlated factors that may drive changes in observed phenology (sunshine, snowpack/snowmelt, soil moisture)
- use of mean annual temperature
- issues with meta-analyses (devil is in the details)

How to develop a species distribution model



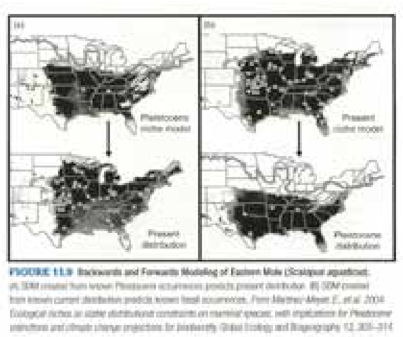
Hannah, 2011

Example application of species distribution model



Hannah, 2011

Evaluating species distribution models with historical observations



Hannah, 2011

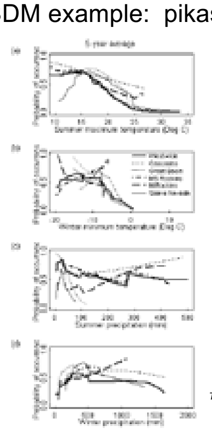
SDM example: pikas

Figure 1. Observed pika occurrence points (plusses), pika subspecies (dashed lines), and modeled suitable habitat for current climate (gray).

Species distribution model of pika

Trook, Buotte, Hicke, unpublished

SDM example: pikas



Probability of occurrence as function of climate variables

Trook, Buotte, Hicke, unpublished

SDM example: pikas

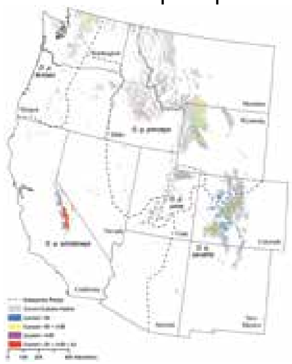


Figure 2. Modeled suitable habitat for American pika for current climate and for climate emission/model projections GFDLCM21/B1, CGCM3/A1B, and GFDLCM21/A2. For the majority of future habitat, more warming leads to a contraction in habitat area upslope (or disappearance). In the small amount of purple area in the northern Rocky Mountains, the GFDLCM21/B1 projection was warmer in the warmest month than the CGCM3/A1B projection.

Projections of future potential habitat based on climate change projections

Trook, Buotte, Hicke, unpublished

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SDM example: pikas

Area of habitat and % of current for climate change projections

[illegible]

Metric	Taxon	Current	B1	%change	A1B	%change	A2	%change
Area (km²)	Ochotona princeps	318,516	58,743	-81.4%	44,116	-86.1%	6,581	-98.2%
	O. p. princeps	185,482	23,020	-87.6%	21,564	-88.6%	580	-99.7%
	O. p. schisticeps	32,969	7,702	-76.6%	5,434	-83.5%	3,047	-90.8%
	O. p. fenisex	20,213	3,714	-80.7%	3,704	-85.6%	52	-99.8%
	O. p. uinta	12,754	2,550	-80.0%	1,225	-90.4%	96	-99.2%
	O. p. saxatilis	59,299	21,757	-63.3%	12,587	-78.8%	1,866	-96.8%
Average patch size (km²)	Ochotona princeps	50.82	39.57	-11.4%	20.25	-65.7%	6.774	-98.9%
	O. p. princeps	63.86	14.43	-77.4%	15.46	-83.8%	2.79	-93.8%
	O. p. schisticeps	23.52	28.64	5.2%	24.15	-8.3%	21.16	-17.1%
	O. p. fenisex	26.97	9.82	-67.1%	10.55	-63.6%	3.53	-87.8%
	O. p. uinta	63.45	34.03	-44.2%	22.60	-64.2%	2.28	-96.4%
	O. p. saxatilis	122.5	62.16	-49.3%	33.39	-72.7%	<1	-98.7%

Trook, Buotte, Hicke, unpublished

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SDM example: pikas

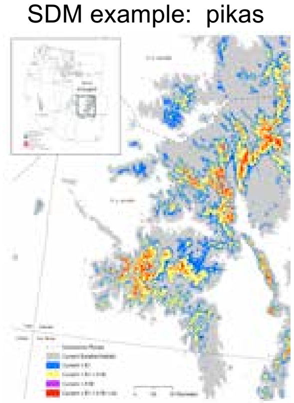

Figure 3. Same as Figure 2 but for an area in southwestern Colorado illustrating increased fragmentation of pika habitat as a result of warming.

Fine spatial resolution projections allowed visualization of habitat fragmentation

Trook, Buotte, Hicke, unpublished

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SDM example: pikas

We couldn't get this work published…why?

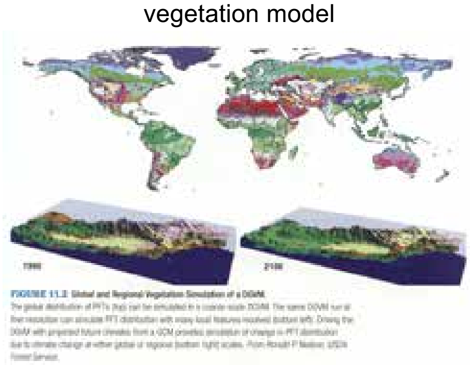
- lack of inclusion of important explanatory variables
  - necessary habitat
    - talus maps of uncertain quality
  - presence of subtalus snow or water
- uncertainty about pika's ability to persist in hot, dry places
  - behavioral change
- uncertainty about importance of other factors
  - snow cover as insulation
  - cold-air drainage through talus slopes

Trook, Buotte, Hicke, unpublished

Flow diagram of process-based ecosystem model

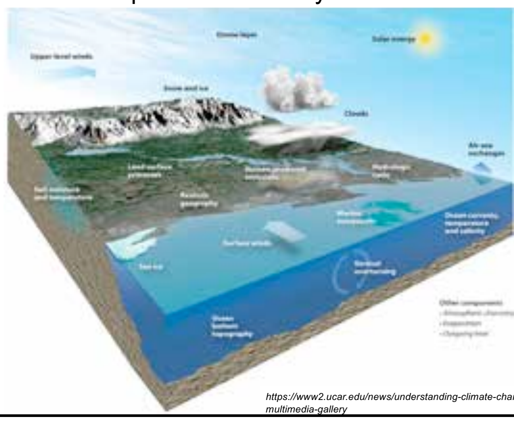
Smith et al., Global Ecology & Biogeography, 2001

Example application of dynamic global vegetation model



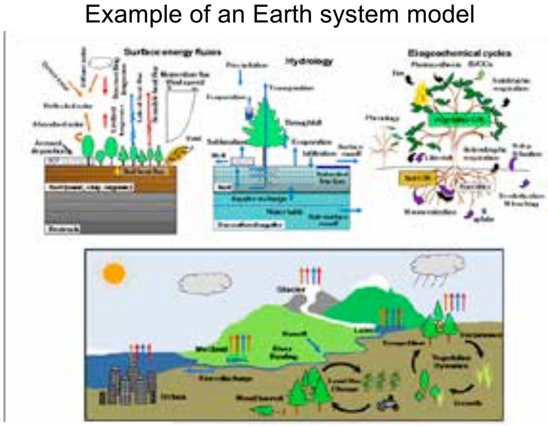
Hannah, 2011

Example of an Earth system model



https://www2.ucar.edu/news/understanding-climate-change-multimedia-gallery

Example of an Earth system model



www.cesm.ucar.edu/models/clm

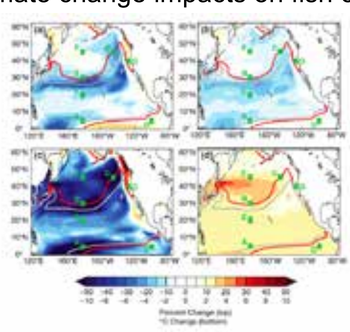
Example application of an Earth system model: climate change impacts on fish catch

%change in primary production

%change in small phytoplankton density

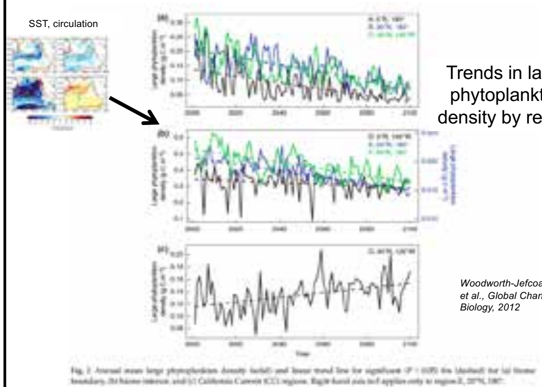
%change in large phytoplankton density

change in sea surface temperatures



Woodworth-Jefcoats et al., Global Change Biology, 2012

Example application of an Earth system model: climate change impacts on fish catch



Trends in large phytoplankton density by region

Woodworth-Jefcoats et al., Global Change Biology, 2012

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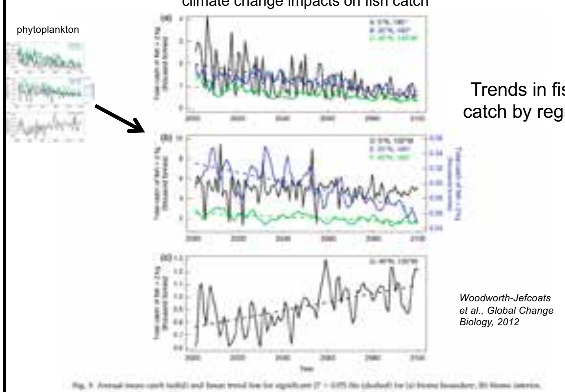
Example application of an Earth system model: climate change impacts on fish catch



Trends in fish catch by region

Woodworth-Jefcoats et al., Global Change Biology, 2012

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