

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)

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Laboratory experiments of $\uparrow\text{CO}_2$

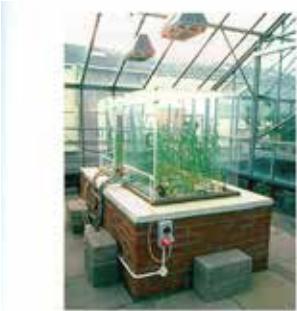


FIGURE 10-3 Laboratory and Greenhouse Experiments.
Controlled enclosures may be used to maintain constant elevated CO_2 levels, whereas greenhouses or other growing devices may be used to manipulate temperature. (Courtesy of ZCR)

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Effect of $\uparrow\text{CO}_2$ for plants with different photosynthetic pathways

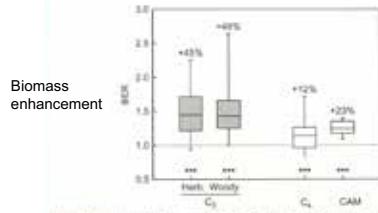


FIGURE 10-5 Increase in Biomass for Different Categories of Species (Herbaceous and Woody, C₃ Plants, C₄ Species, and CAM Species).
Graphs show an increase in biomass enhancement rates, a measure of increase in biomass. Results just as in Fig. 10-4 include the 5th quartile (horizontal line), 25th quartile (line of box), 50th median of box, 75th (top line of box), and 95th (upper horizontal line) percentile of the distribution. From Poorter, H. and Niinemets, M. J., 2003. Plant growth under conditions of elevated CO_2 : On winners, losers and functional groups. New Phytologist 157, 179–198.

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Effect of $\uparrow\text{CO}_2$ diminishes when other factors (here, competition) are present

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

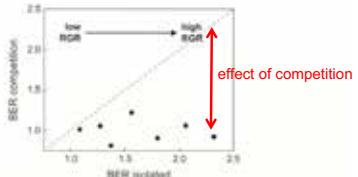


FIGURE 10.7 Biomass Enhancement for Seven Tropical Plant Species Grown in Isolation and in a Mixed Community.
The CO₂ enhancement observed in the isolated trial is not evident in the mixed community.
From Poorter, H. and Reich, P. B., 2002. Plant growth and competition at elevated CO₂: On winners, losers and functional groups. *New Phytologist* 157, 125–138.

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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 Chasity Munn.
(b) From the National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara.

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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 white soil. Open-top chambers preserve plant and soil relationships over a limited area. Source: Forest Fertilization Research Institute.

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open-top chamber

cover to increase nighttime infrared radiation

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

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Different field experiment methods

Free air CO₂ enrichment (FACE) experiments



FIGURE 10.11 Free Air CO₂ Enrichment (FACE) Experiments.
FACE experiments use massive diffusers to elevate CO₂ 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 Nickelberger, Swiss FACE Experiment (ETH, Zurich). (c) From Brookhaven National Laboratory.

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Responses of ecosystem structure and function to warming among locations

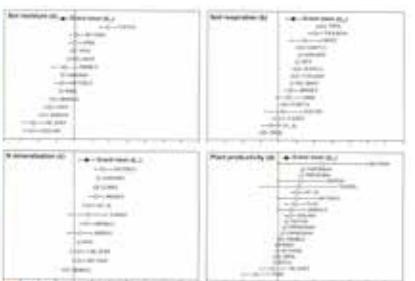


FIGURE 10.12 Responses to Warming.
The effects of warming on root biomass, net respiration, net mineralization, and plant productivity are shown for 40 sites located throughout the world. Mineralization rates shown in each study site are indicated by open circles. Error bars indicate 95% confidence intervals. The asterisk indicates no effect. (From Hik, J., et al. 2005. A meta-analysis of the response of soil respiration, net soil mineralization, net primary production, and plant productivity to experimental ecosystem warming. *Oecologia* 145: 844–855.)

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Over time, the growth enhancement of ↑CO₂ diminishes

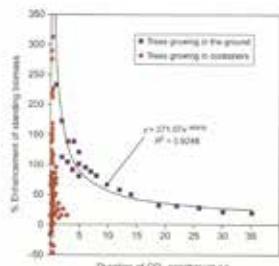


FIGURE 5.13 Acclimation in Experimental and Natural Settings.

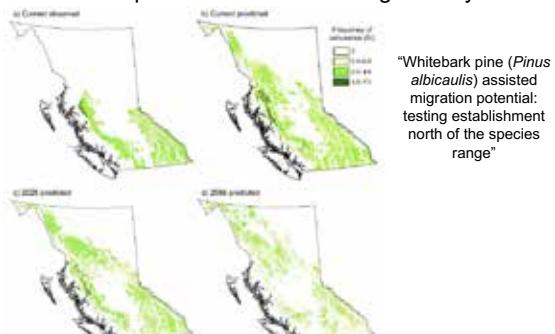
Single start experiments seldom span long enough time frames to detect acclimation. Whole-ground experiments, usually conducted over longer time frames, clearly show the effect of acclimation. From data of B. B. Tausch (2000) long-term responses of trees to atmospheric CO₂ enrichment: Global Change Biology 5: 483–495.

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Field experiments: tree seedling viability



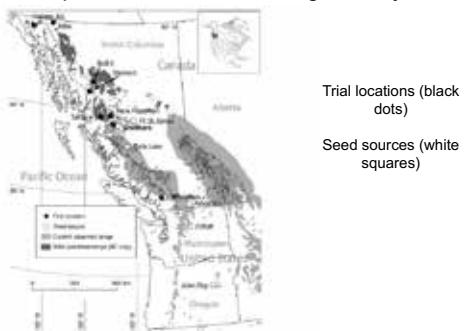
"Whitebark pine (*Pinus albicaulis*) assisted migration potential: testing establishment north of the species range"

McLane and Aiken,
Ecol. Appl., 2012

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Field experiments: tree seedling viability



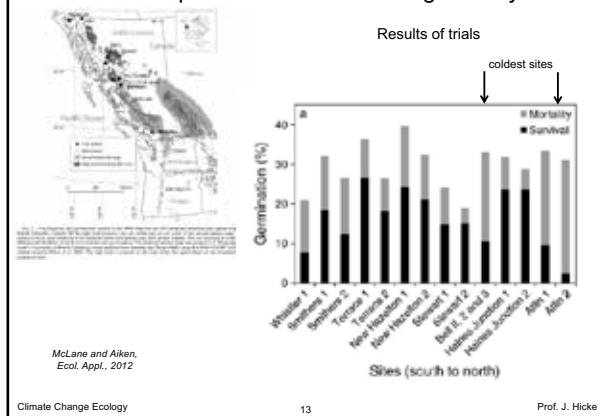
Trial locations (black dots)
Seed sources (white squares)

McLane and Aiken,
Ecol. Appl., 2012

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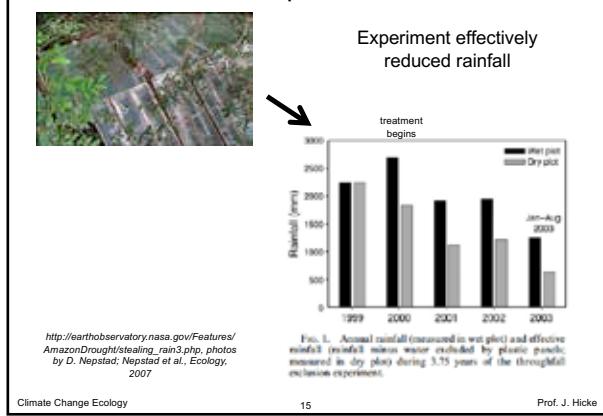
Field experiments: tree seedling viability

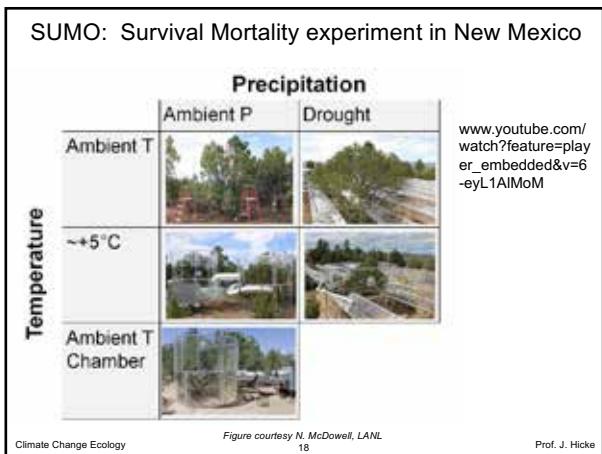
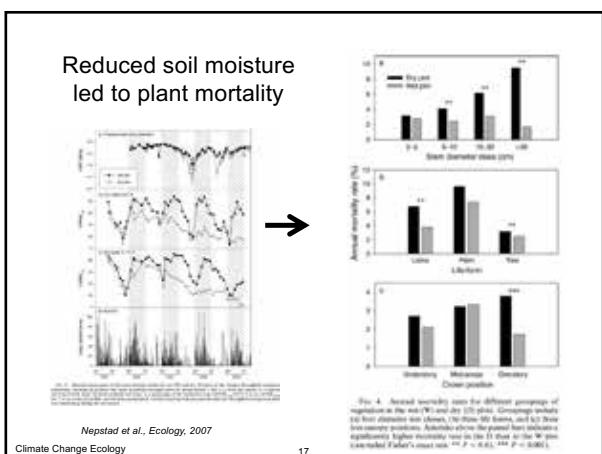
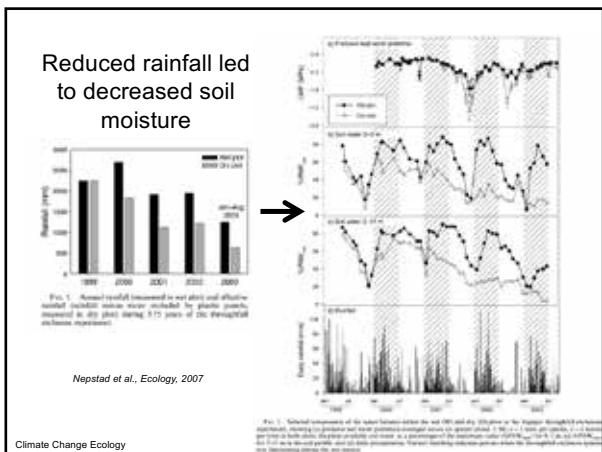


Different field experimental methods



Different field experimental methods





Dangers of misinterpreting experiments

LETTER

Warming experiments underpredict plant phenological responses to climate change

S. R. Hikosaka, J. A. Clark, M. K. Lusk, S. J. Lusk, J. M. McDonnell, T. A. Moran, S. H. Nagy, J. L. Oborny, M. D. Sturm, P. G. Vittorini

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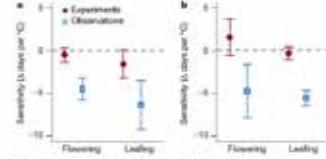


Figure 2 Estimates of the flowering and leafing sensitivities. The minimum from the mixed effects model (presented as mean \pm s.e.m.), including the random effects of site and species, show that experiments underpredicted the magnitude of plant responses to interannual temperature variation for all species sampled (a) and for the species that are common to both the experimental and the observational data sets (b). The regions above the dashed grey line represent positive sensitivities, meaning that the species' phenological events are advanced with increasing temperature. The regions below the dashed grey line represent negative sensitivities, meaning that the species' events advance with increasing

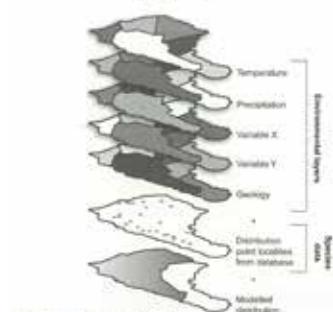
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Possible explanations

- 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

Statistical overlay



Downloaded by J. E. Henningsen et al. (2006)

Species distribution models (SDMs) are statistical tools that can be used to predict the likelihood of occurrence of a species in a given area. They are based on the assumption that the presence or absence of a species is influenced by environmental factors such as temperature, precipitation, and vegetation. SDMs typically involve collecting data on the presence or absence of a species at various locations, along with information on the environmental conditions at those locations. This data is then used to build a statistical model that relates the environmental variables to the presence or absence of the species. The resulting model can then be used to predict the likelihood of occurrence of the species in new areas based on their environmental conditions. SDMs have been used to predict the potential range of many species in response to climate change, and they have also been used to predict the impact of habitat loss and fragmentation on species distributions.

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Example application of species distribution model

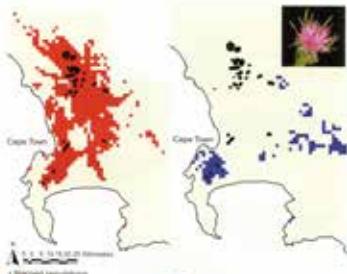


FIGURE 11.1 Example of SDM output. SDM output for a species occurring from the Cape Fold Belt region of South Africa. Current recorded range is shown in red, and future modeled range is shown in blue. Known occurrence points for the species are indicated by black circles. (Figure modified from Maggs)

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Evaluating species distribution models with historical observations

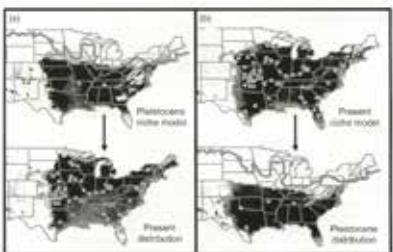


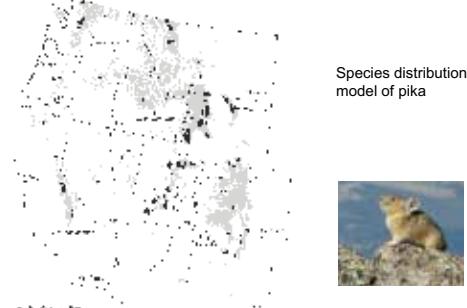
FIGURE 11.9 Backwards and Forwards Modeling of Eastern Mole (*Scapanus aquosus*).
 (a) SEM model from known Pleistocene occurrences predicts present distribution; (b) SDM creates
 from known current distribution predicts known fossil occurrences. From Martinez-Meyer E., et al. 2004.
 Ecological niches in climate distribution constraints on mammal species, with implications for Pleistocene
 migrations and climate change projections. *for Biodiversity, Global Ecology and Biogeography* 13:305–314.

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SDM example: pikas



Species distribution
model of pika



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

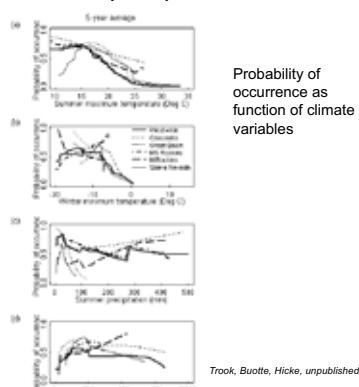
Trook, Buotte, Hicke, unpublished

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SDM example: pikas

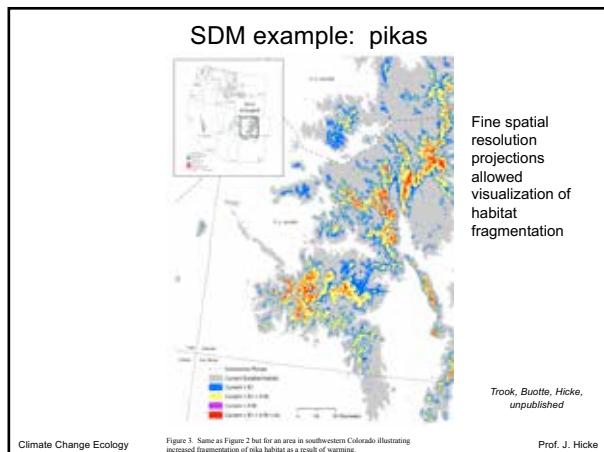
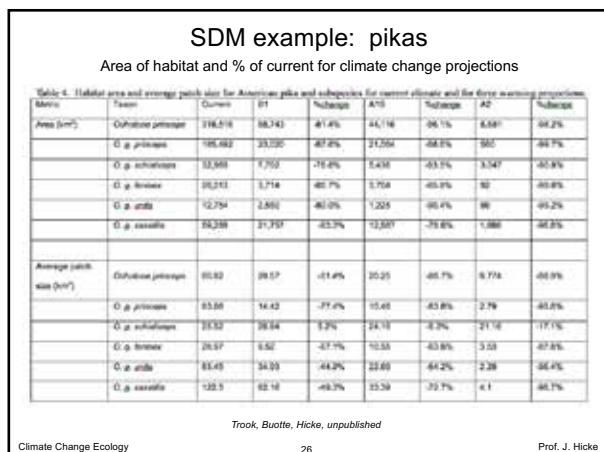
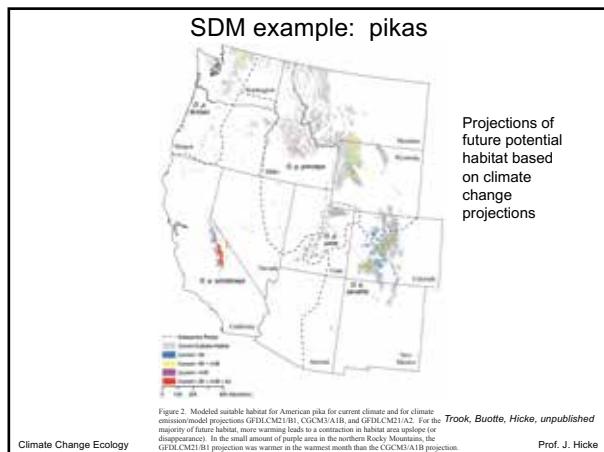


Probability of
occurrence as
function of climate
variables

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 subalpine 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

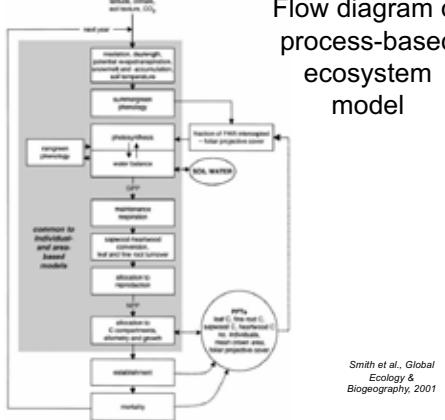
Trook, Buotte, Hicke, unpublished

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Flow diagram of process-based ecosystem model



Smith et al., Global
Ecology &
Biogeography, 2001

Example application of dynamic global vegetation model



FIGURE 15.2 Global and Regional Vegetation Simulation of a DGVN.
The global distribution of PFTs (this can be simulated in a coarse scale GCM). The same DGVN at a finer resolution can simulate PFT distribution with many local features (isolated shrubs left). Driving the DGVN with projected future climates from a GCM provides simulation of change in PFT distribution due to climate change at either global or regional (bottom right) scales. From: Ronald P. Nelson, USFS Forest Service.

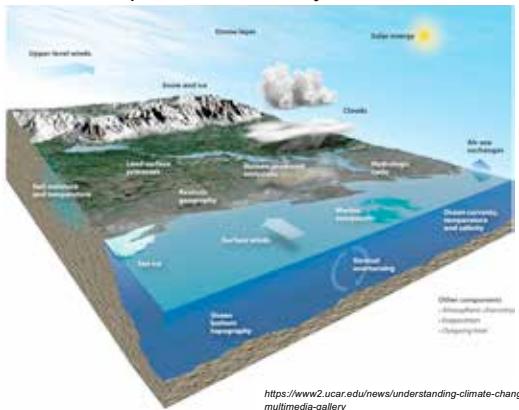
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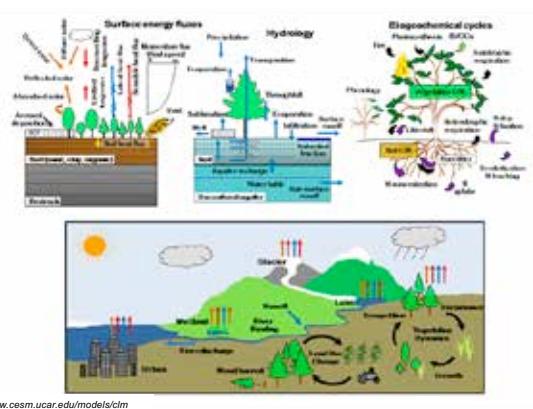
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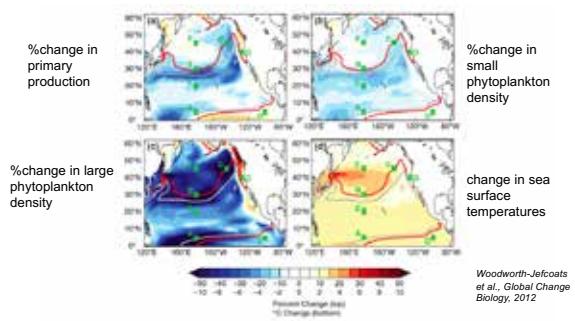
Example of an Earth system model



Example of an Earth system model



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



Dig. 3. Change, in present or °C as noted, from the beginning to the end of the 21st century (2080–2090) modelled for (a) primary production (%), (b) small phytoplankton density (10⁻³), (c) large phytoplankton density (10⁻³), and (d) SST (°C). Isolines boundaries at the beginning and end of the century are marked in grey and red, respectively. Current isolines and letters identify the areas 2° × 2°

