Adaptive Management of Critical Transitions in the Lake Champlain Basin

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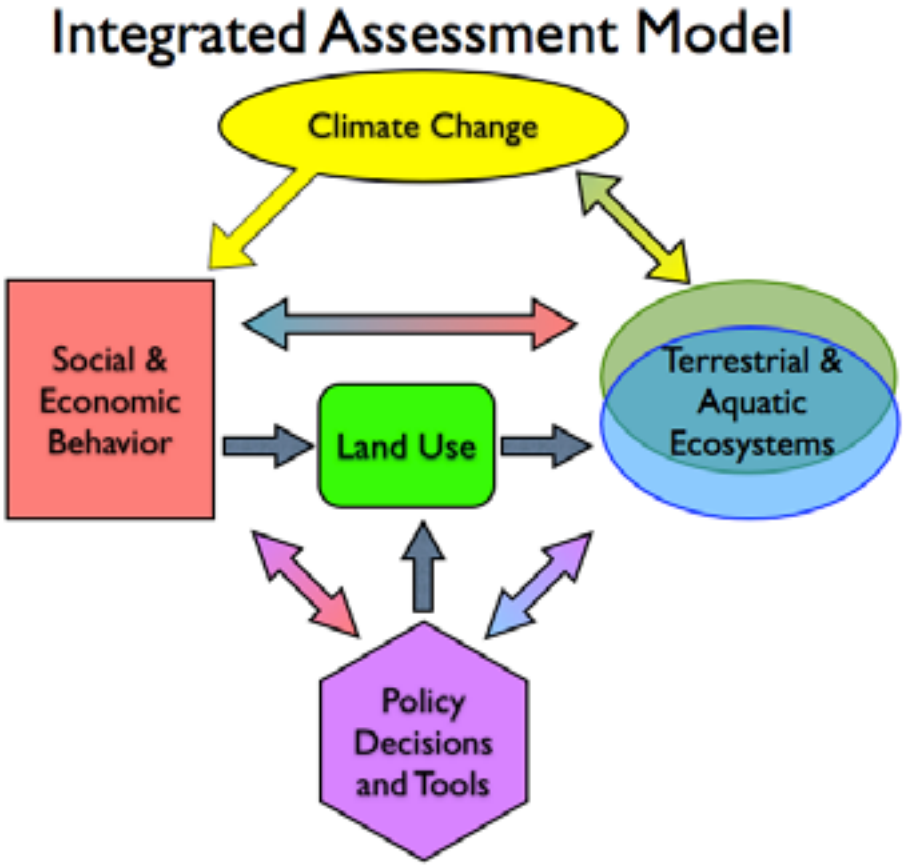
The Overarching RACC Question

How will the interactions of climate change and land use alter hydrological processes and nutrient transport from the landscape, internal processing and eutrophic state within the lake, and what are the implications for adaptive management strategies?



The Core RACC Research Questions

- Q1: What is the relative importance of endogenous (in-lake) processes versus exogenous (to-lake) processes to **eutrophication** and **harmful algal blooms**?

- Q2: Which **alternative stable states** can emerge in the watershed and lake resulting from **non-linear dynamics** of climate drivers, lake basin processes, social behavior, and policy decisions?

- Q3: In the face of **uncertainties** about climate change, land use and lake response scenarios, how can **adaptive management interventions** be designed, valued, and implemented in the multi-jurisdictional region?

Alternate Stable States in the Lakes

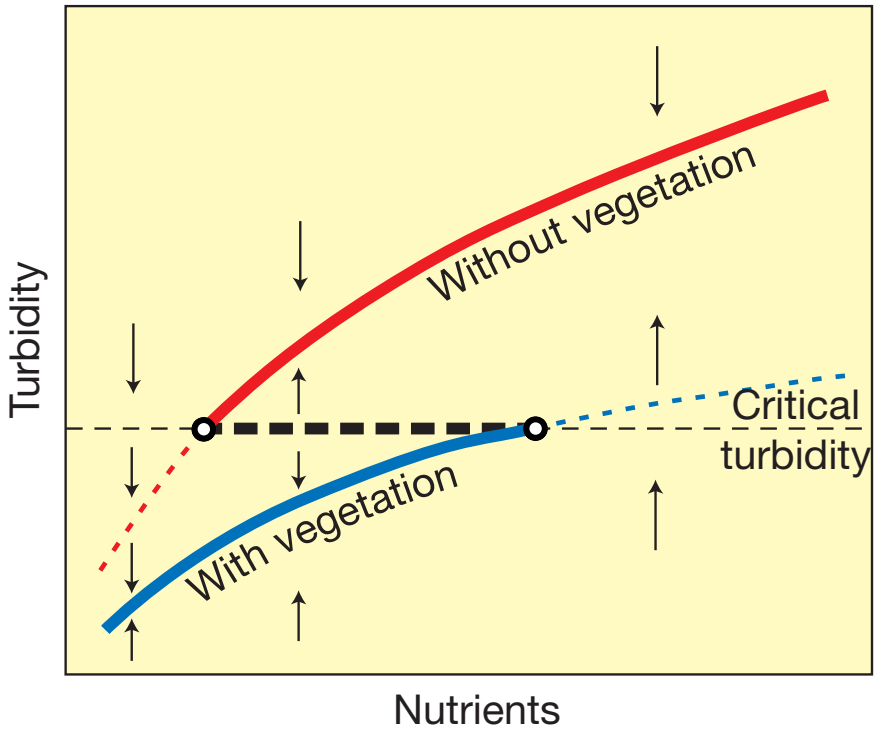


Figure 5 A graphical model[60] of alternative stable states in shallow lakes on the basis of three assumptions: (1) turbidity of the water increases with the nutrient level; (2) submerged vegetation reduces turbidity; and (3) vegetation disappears when a critical turbidity is exceeded. In view of the first two assumptions, equilibrium turbidity can be

Scheffer et al. 2001 *Nature*

Critical Transitions in Lake Systems

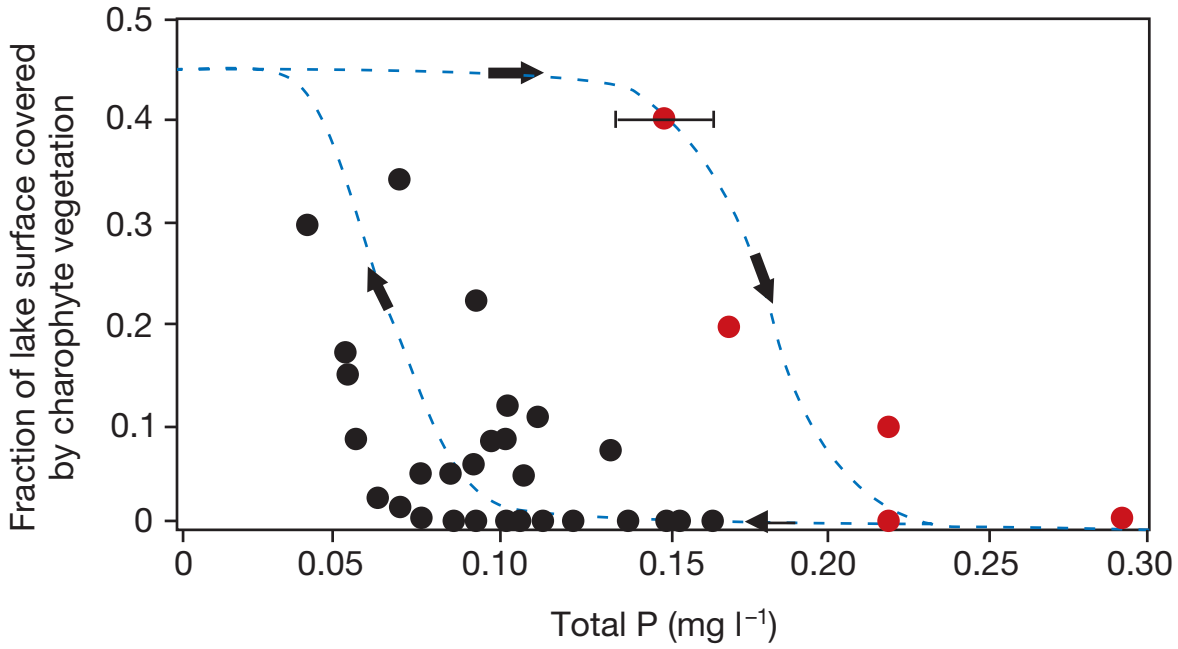
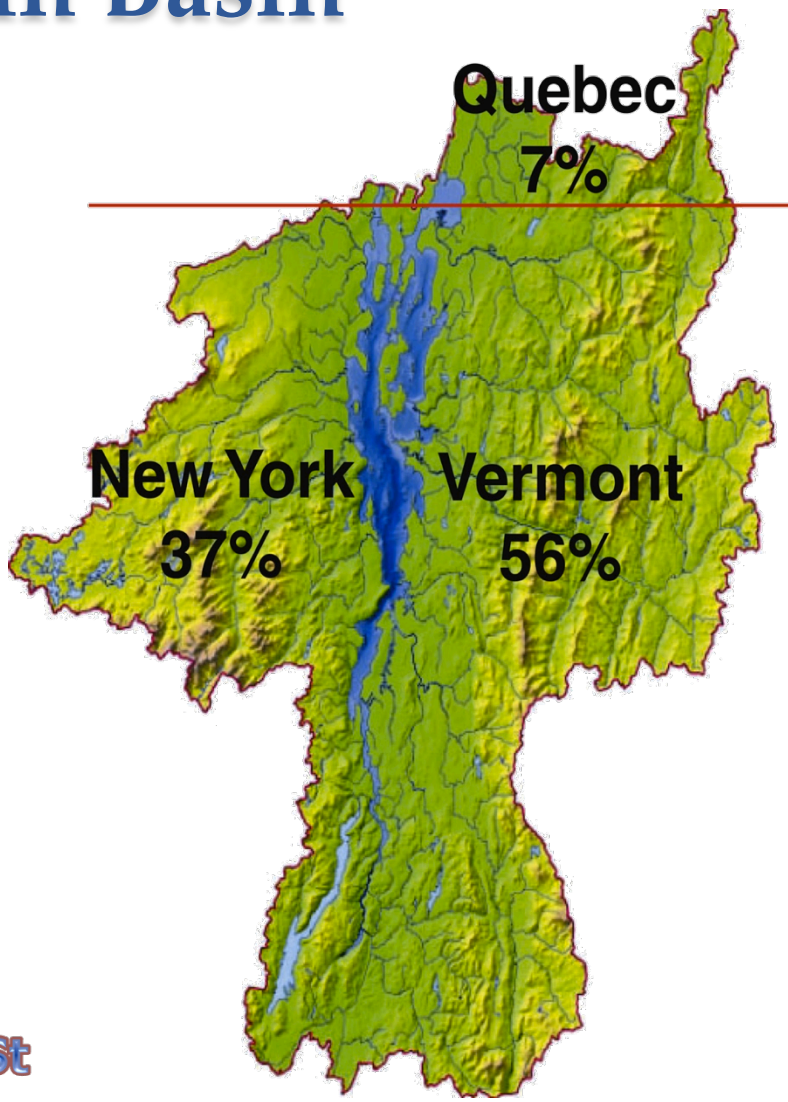


Figure 4 Hysteresis in the response of charophyte vegetation in the shallow Lake Veluwe to increase and subsequent decrease of the phosphorus concentration. Red dots represent years of the forward switch in the late 1960s and early 1970s. Black dots show the effect of gradual reduction of the nutrient loading leading eventually to the backward switch in the 1990s. From ref. 59.

Scheffer et al. 2001 *Nature*

Lake Champlain Basin

- The Basin: 21,326 square kilometers
  - The Drainage Basin is 18.9 times as large as the Lake
- The Lake: 1,127 square kilometers
  - Over 122 meters deep
  - 193 kilometers long
- The Richelieu River
  - Lake Champlain waters enter the Richelieu River and flow north to the St Lawrence River



Phosphorus Concentrations By Lake Segment

Figure 3

MEETS THE TARGET

DOES NOT MEET THE TARGET

QUÉBEC

VT

NY

ISLE LA MOTTE*
Target = 14 µg/L
* average of two stations

CUMBERLAND BAY
Target = 14 µg/L

MAIN LAKE
Target = 10 µg/L

PORT HENRY
Target = 14 µg/L

SOUTH LAKE A
Target = 25 µg/L

SOUTH LAKE B
Target = 54 µg/L

MISSISQUOI BAY
Target = 25 µg/L

ST ALBANS BAY
Target = 17 µg/L

NORTHEAST ARM
Target = 14 µg/L

MALLETTS BAY
Target = 10 g/L

BURLINGTON BAY
Target = 14 µg/L

SHELBURNE BAY
Target = 14 µg/L

OTTER CREEK
Target = 14 µg/L

Average Phosphorus Concentrations 2007-2011

- >= 41 µg/L
- 21 - 40 µg/L
- 16 - 20 µg/L
- <= 15 µg/L

µg/L = micrograms/liter

DATA SOURCE: Long Term Monitoring Program (LCBP, VTANR, NYSDEC)

South Lake

- Exceeds P targets
- Excess weed growth
- Water chestnut and Eurasian watermilfoil
- Much of the watershed is intensively farmed

Missisquoi Bay

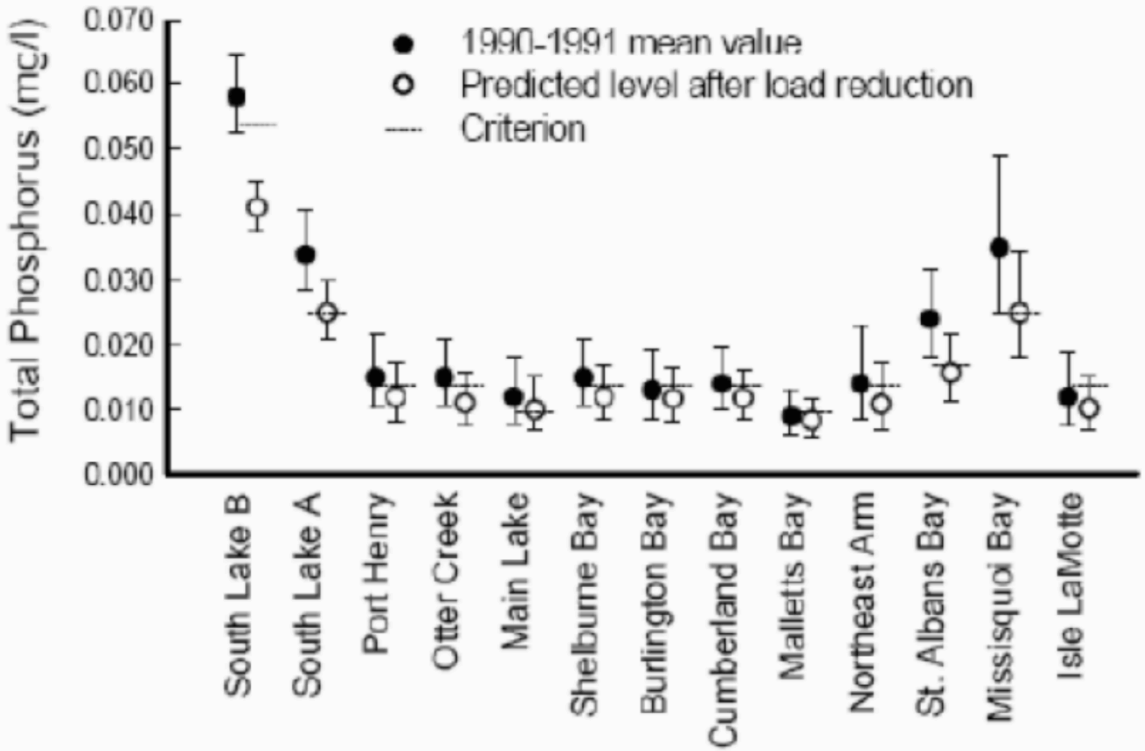
- Greatly exceed P target
- Seasonal BGA blooms
- Extensive agriculture

Northeast Arm

- Exceeds P targets
- Seasonal BGA blooms
- Eurasian watermilfoil
- Extensive agriculture and urban areas

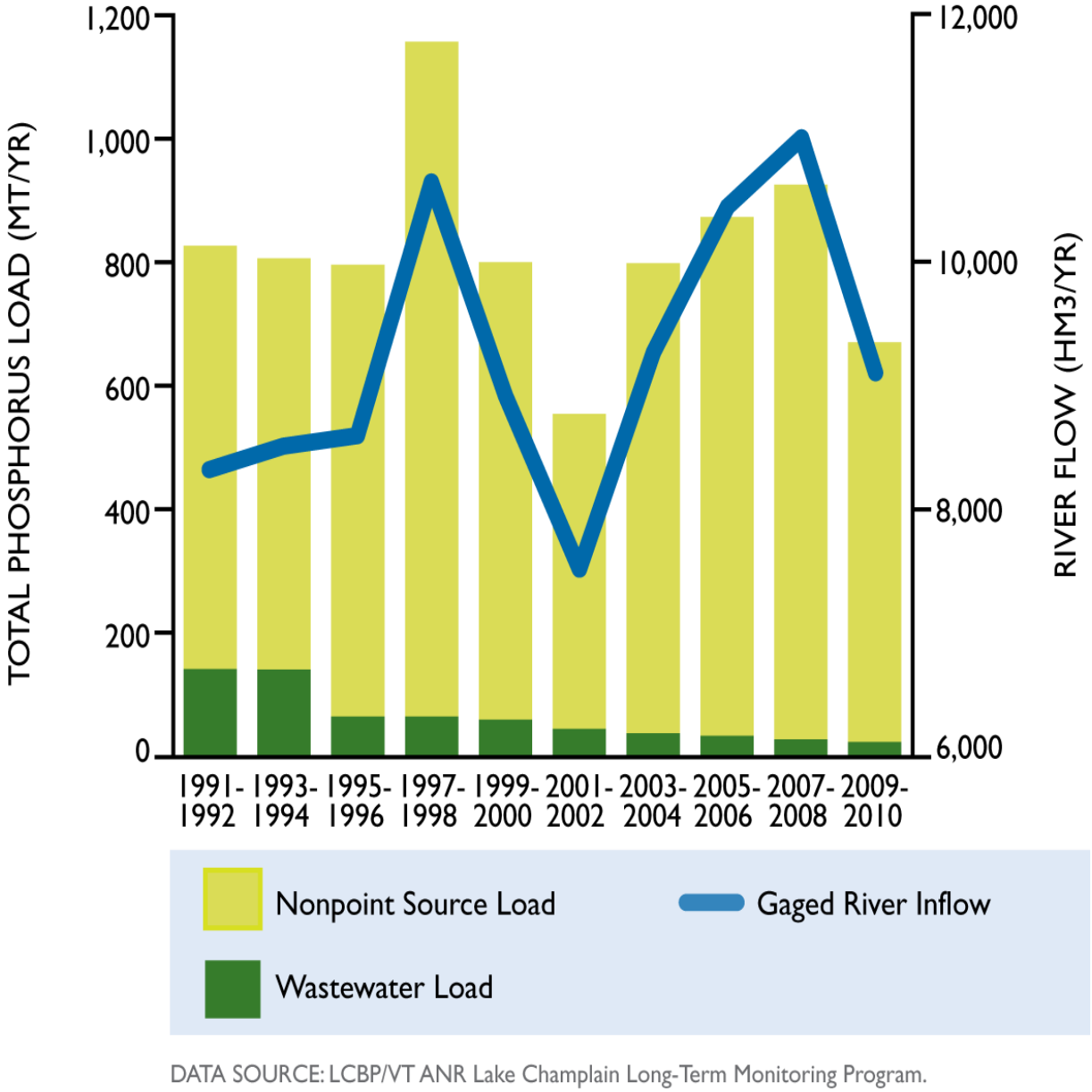
Managing with Uncertainties and Value Conflicts

Figure 1. Predicted Phosphorus Concentrations Following Load Reductions (Reproduced from the Lake Champlain Phosphorus TMDL, p. 17)

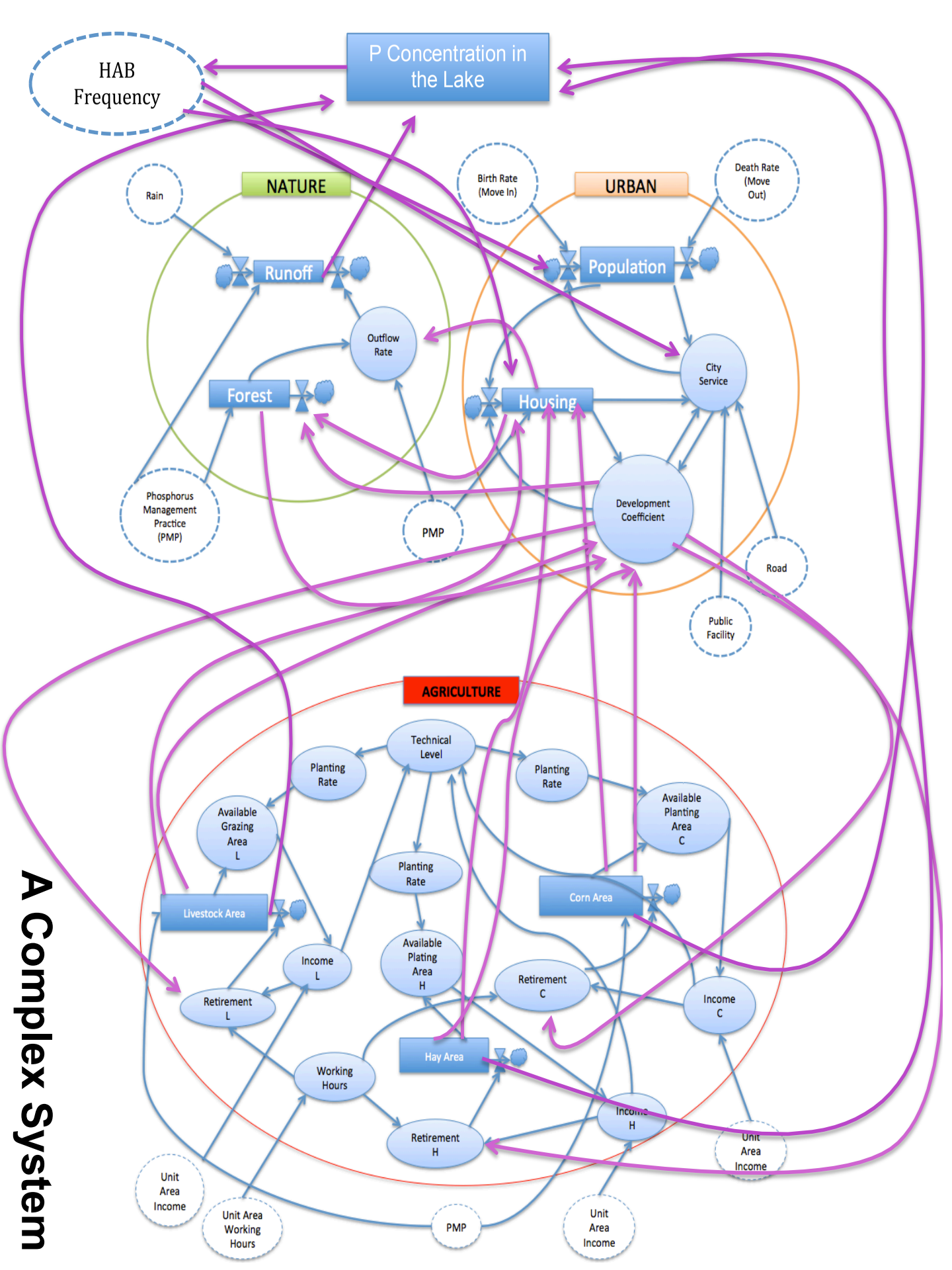


Predicted phosphorus concentrations in Lake Champlain segments following targeted load reductions, compared with 1991 measured mean levels and in-lake criteria values (from Table 2). Error bars show 95% confidence intervals for the existing mean and predicted phosphorus concentrations. The predicted concentrations and criteria values are listed below. (Figure modified from Vermont DEC and New York State DEC 1997.)

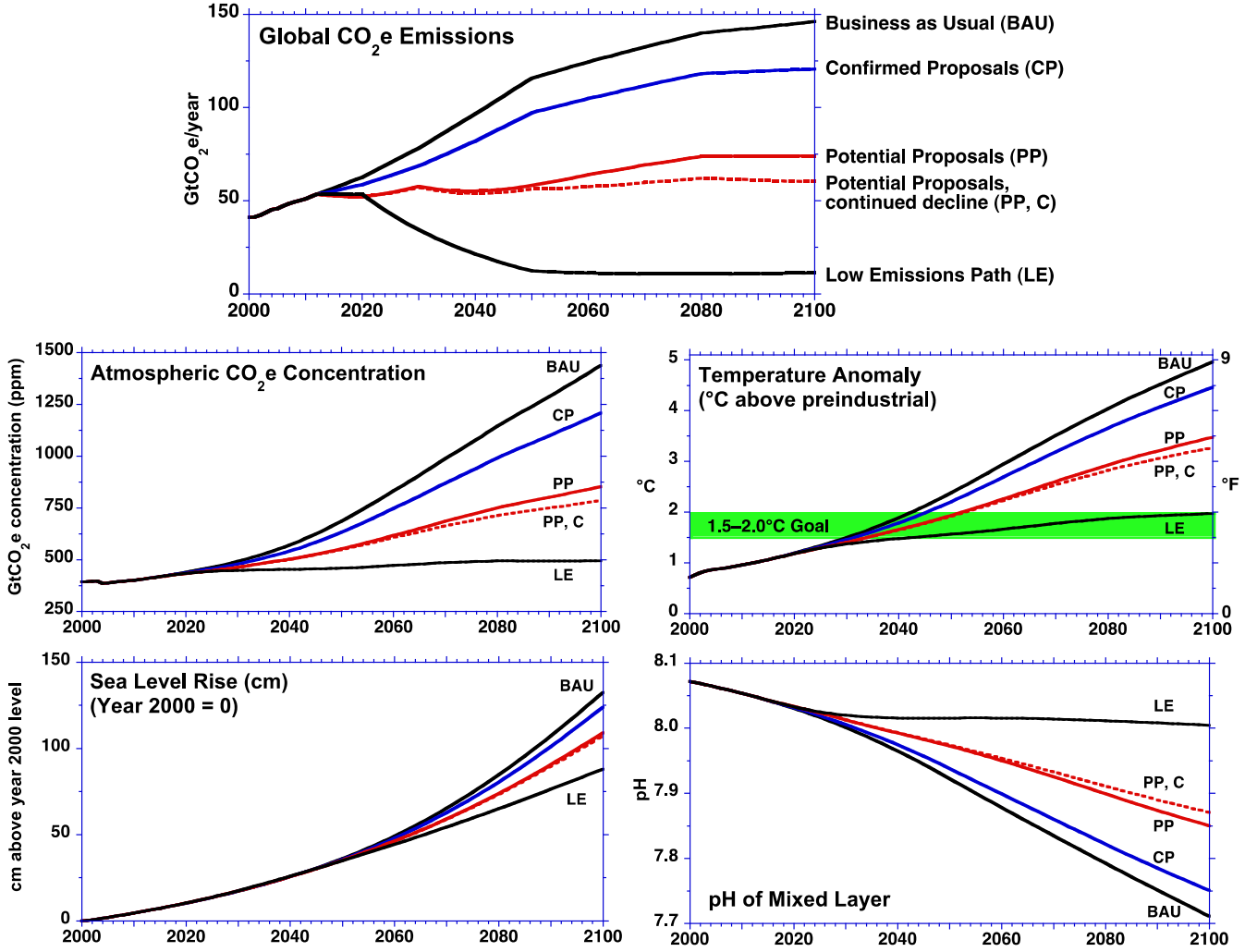
The total Phosphorus load goes up with higher river inflows (expected to be even higher under A1F1 climate change scenario)



Source: Howland 2012


HAB Frequency
P Concentration in the Lake
NATURE
URBAN
AGRICULTURE
Rain
Runoff
Outflow Rate
Forest
Phosphorus Management Practice (PMP)
PMP
Birth Rate (Move In)
Death Rate (Move Out)
Population
City Service
Housing
Development Coefficient
Road
Public Facility
Technical Level
Planting Rate
Planting Rate
Planting Rate
Available Grazing Area L
Available Planting Area C
Livestock Area
Corn Area
Income L
Available Plating Area H
Retirement C
Income C
Retirement L
Hay Area
Working Hours
Income H
Retirement H
Unit Area Income
Unit Area Income
Unit Area Working Hours
PMP
Unit Area Income
A Complex System

Mitigation & Adaptation to Climate Change



Mitigation at global scale

Versus

Adaptation at local to regional scales

Fig. 6. C-ROADS assessment of pledges under the Copenhagen Accord, as of December 2011. Results shown for BAU (A1FI), total confirmed proposals, potential proposals, and potential proposals assuming continued emissions decline after the pledge horizon. The "Low Emissions Path" yields expected warming of 2 °C by 2100. http://climatescoreboard.org provides updates and documentation

Sterman et al 2012

Adaptation Strategies

- "Spontaneous" Versus "Planned" Adaptation

- "Planned" Adaptation Strategies in Agriculture
  - **Technological Developments** (crop development, early warning systems, irrigation systems)
  - **Government Programs** (subsidy and grant programs, insurance programs, resource management)
  - **Farm production practices** (crop diversity, intensification level, cover cropping, buffers, BMPs)
  - **Farm financial management** (crop insurance, crop shares and futures, income stabilization programs, household income)

Zia 2012 & Smit and Skinner 2002

Adaptive Management of Critical Transitions

- **"Foresight"** in the face of uncertainties
  - When will critical transitions take place?

- **Value Pluralism**
  - What to do in the face of conflicting values?

- **Experimental Interventions**
  - What type of social and policy learning is taking place from real-world experimental policy and management interventions?

Communicating Climate Risk: Experimental Surveys in 2010 and 2012

Numerical to Verbal

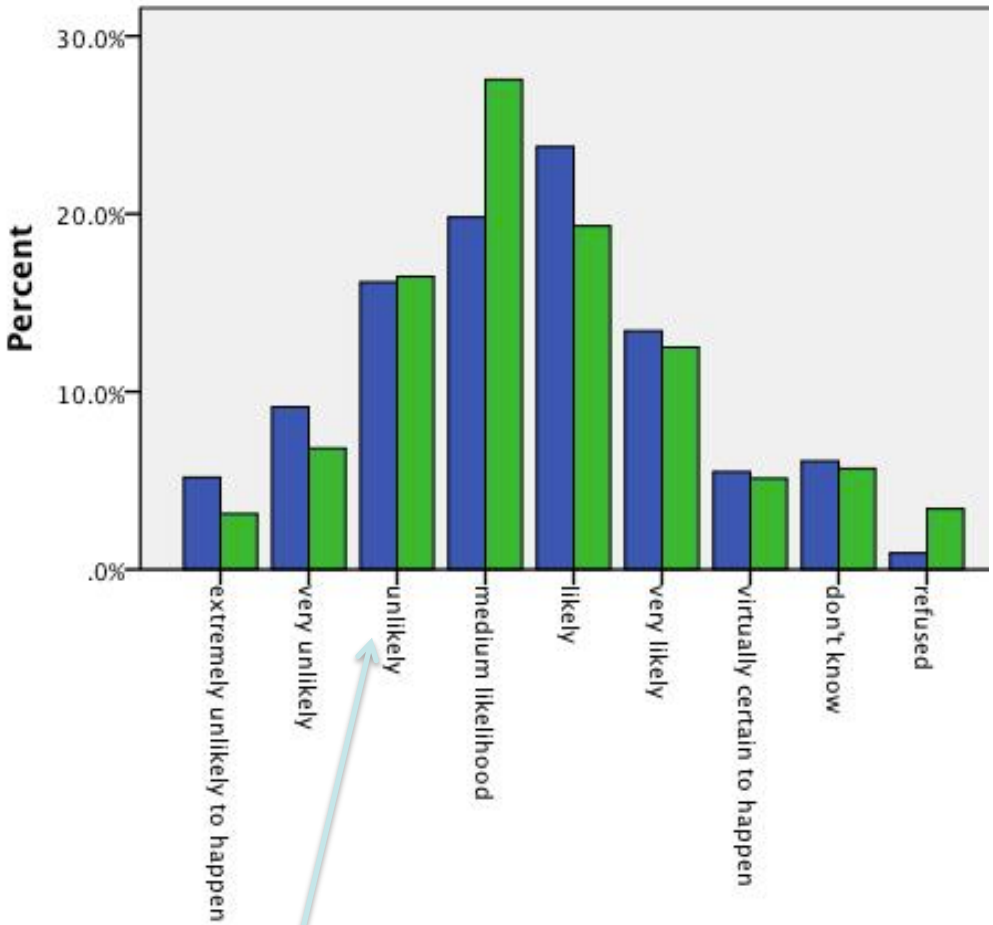
Climate change experts predict that there is a **20%** chance that annual snowfall in Vermont will be half of its historical levels by 2020. Which of the following language would you use to describe to your friends the chances of this happening? This is...

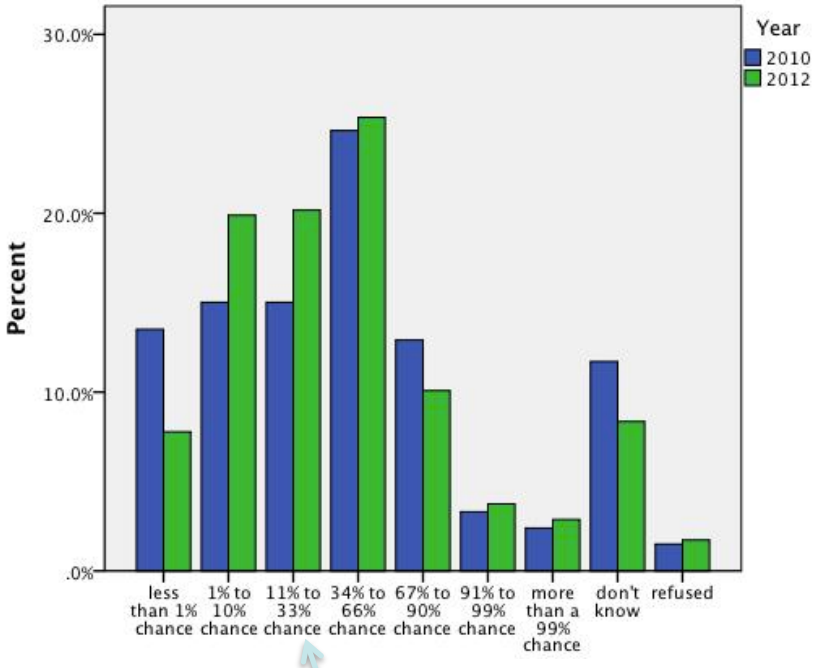
1. Extremely unlikely to happen
2. Very unlikely
3. **Unlikely**
4. Medium likelihood
5. Likely
6. Very likely
7. Virtually certain to happen

Verbal to Numerical

Climate change experts predict that it is **unlikely** that annual snowfall in Vermont will be half of its historical levels by 2020. Which of the following would you use to describe to your friends the chances of this happening? There is a...

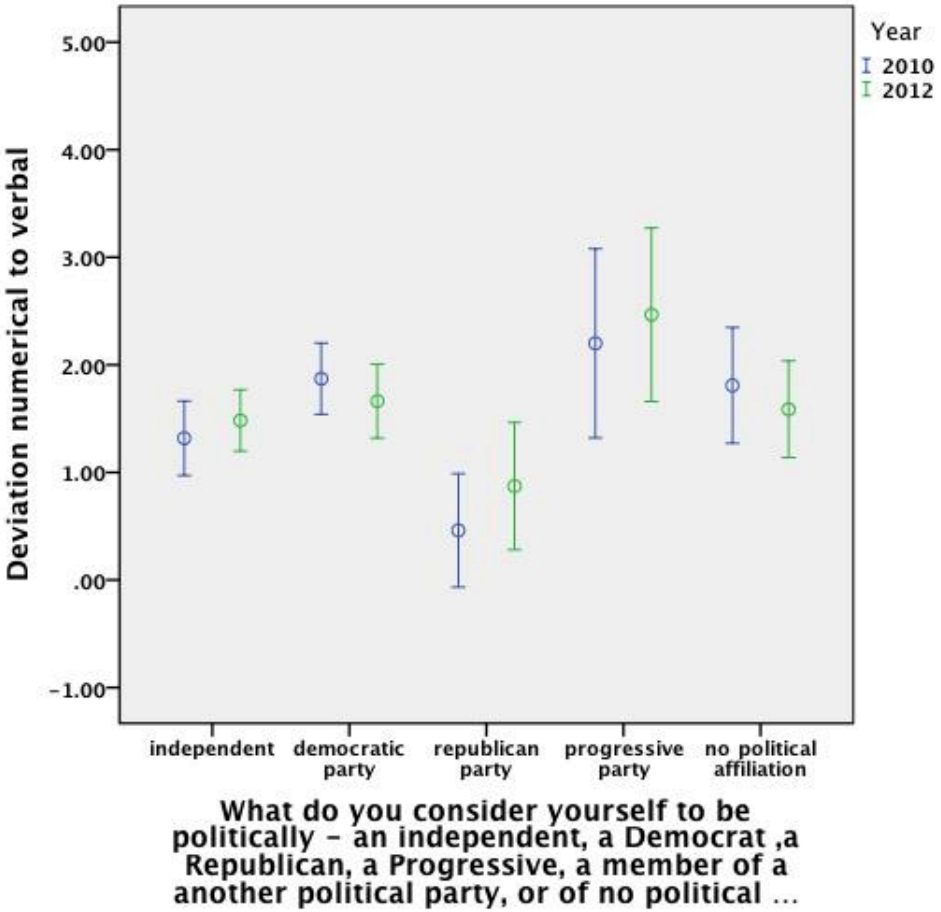
1. less than 1% chance
2. 1% to 10% chance
3. **11% to 33% chance**
4. 34% to 66% chance
5. 67% to 90% chance
6. 91% to 99% chance
7. more than a 99% chance of this happening

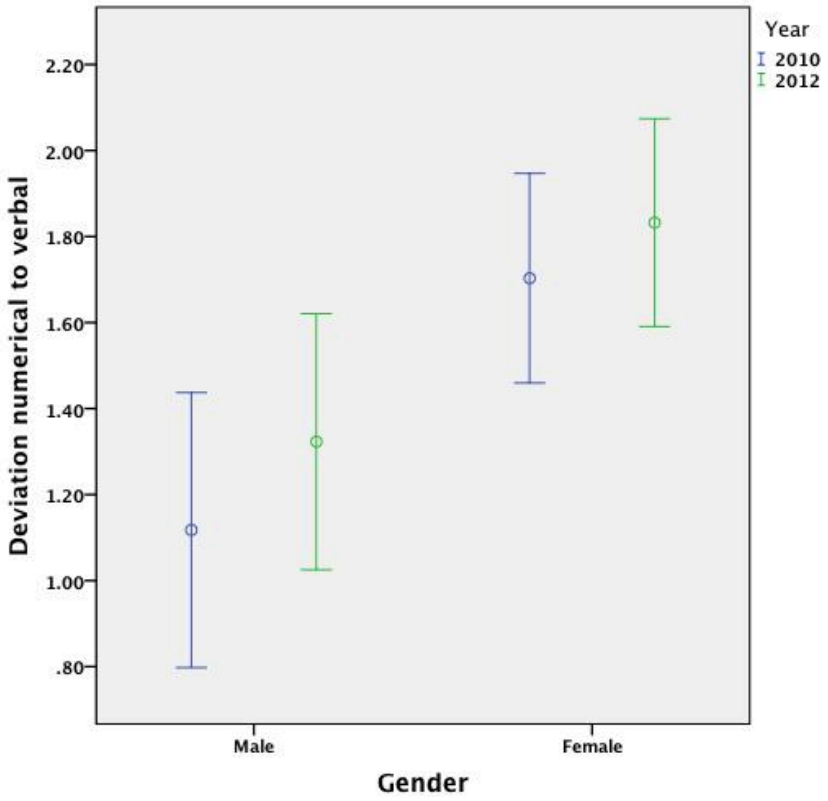




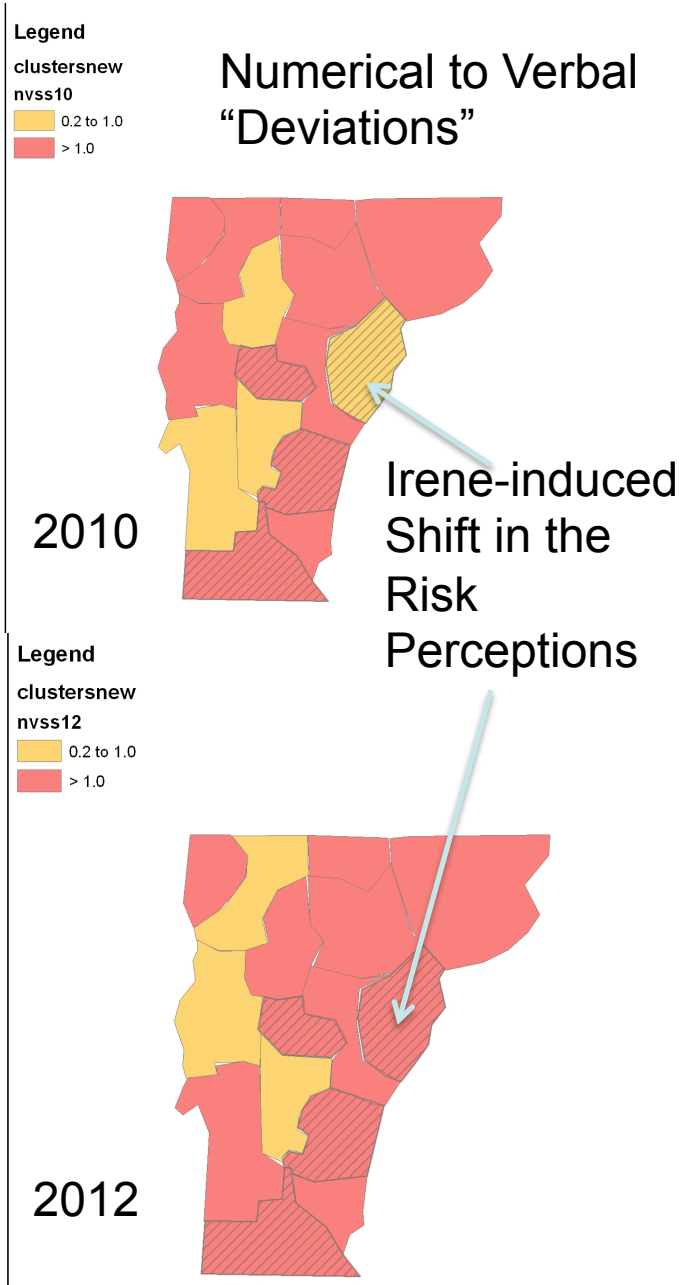
Numerical to Verbal: Less than 20% of the sample correctly interpreted the uncertain forecast (N=680)

Verbal to Numerical: Less than 20% of the sample correctly interpreted the uncertain forecast (N=680)





Under- or Over-estimation of the Uncertain Risk Measured by “Deviation” from the IPCC-Expected Result



Zia, Bomblies, Koliba and Betts, In Prep.

Climate Change Induced extreme events can cause both transient and permanent shifts in the risk perceptions, which in turn can impact the evolution of policy and governance responses to manage critical transitions