Weight of Evidence for Re-Eutrophication of the Great Lakes
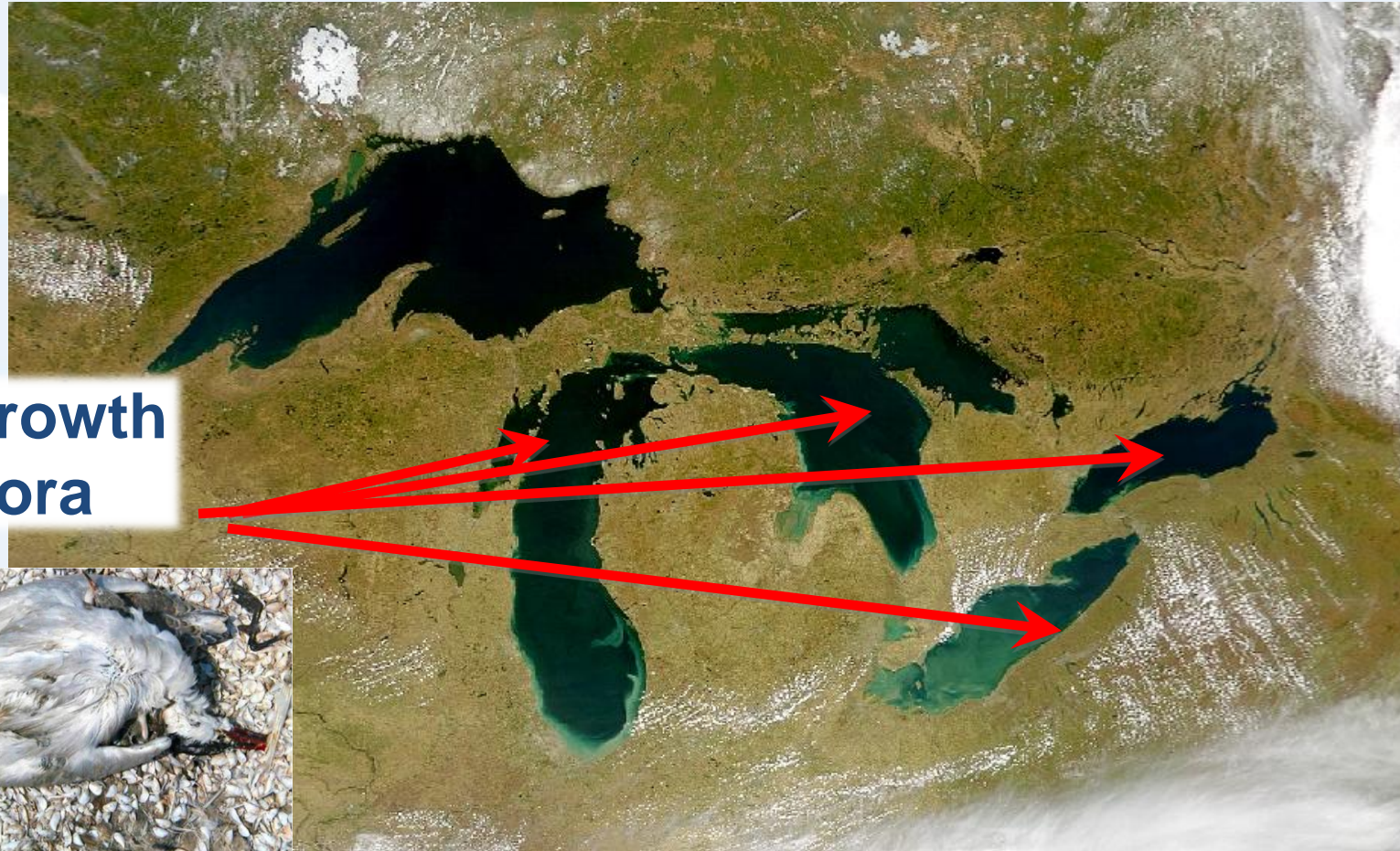
Joseph F. Koonce Case Western Reserve University
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Nicole K. S. Barker, Misun Kang, and Jan J.H. Ciborowski University of Windsor

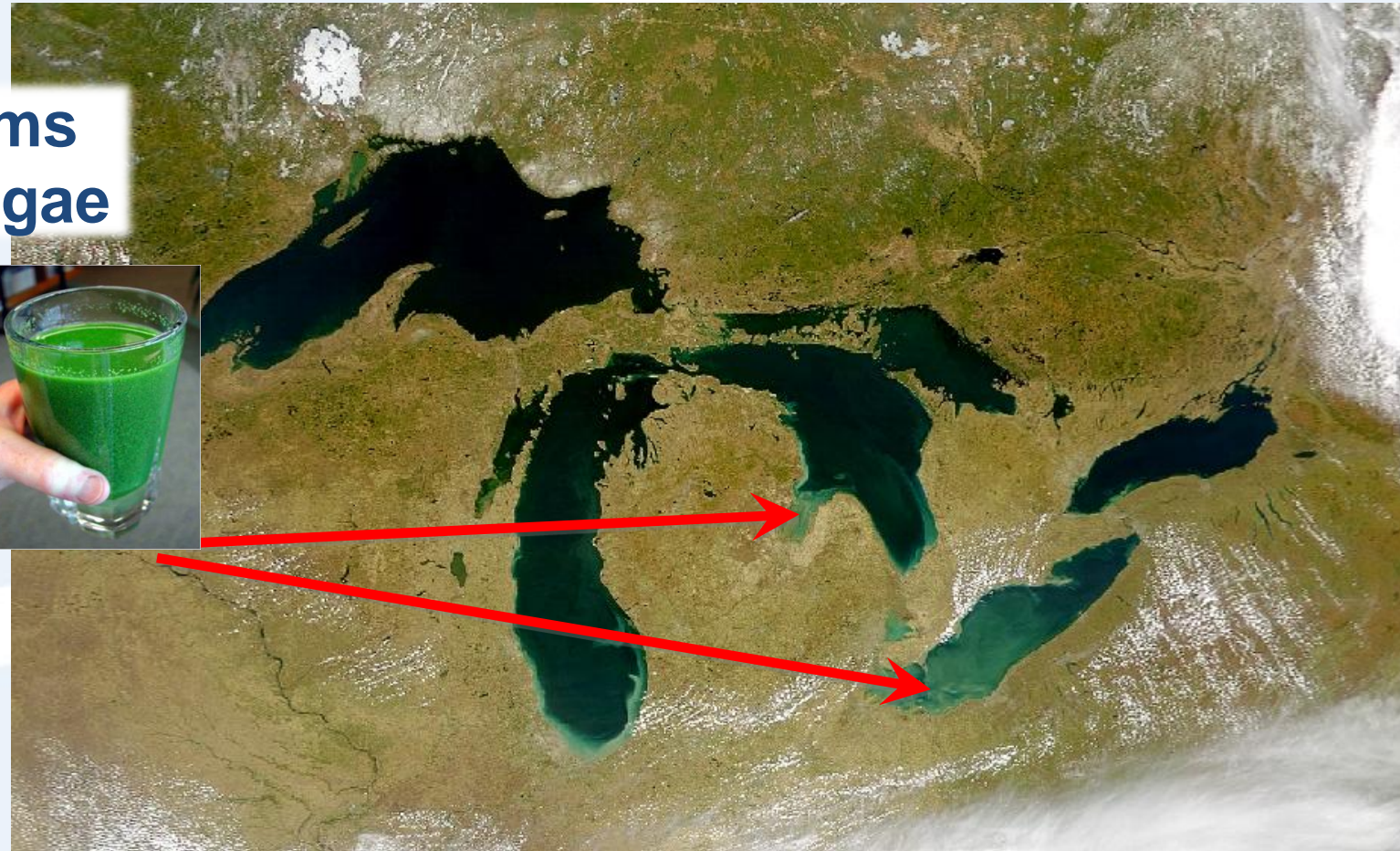Presentation for Lake Erie Millennium Network Conference, April 27-29, 2010

Concern with Re-emergence of Eutrophication

Nuisance Growth of Cladophora

Concern with Re-emergence of Eutrophication

Nuisance Blooms of Blue-green Algae

Ambiguity of Cause and Effect Linkages

Process

- Review of scientific literature on recent eutrophication trends
- Scientists' Eutrophication FCM Workshop held Feb 17-18, 2009
- Stakeholder Eutrophication FCM Workshop held March 26, 2009
- Literature-based FCM conducted March 2010

Findings

- Preliminary analysis of FCMs show re-eutrophication has complex causation
- FCMs confirm the contribution of both external and internal factors to symptoms of eutrophication with literature support
- WOE is insufficient to justify any particular management action to affect symptoms
- Full evaluation of consensus FCM will require more extensive synthetic analysis of literature
- Lack of understanding of contributions of physical processes hinders inferences.

Weight of evidence (WOE) and truth value

- In the absence of *any* evidence, the probability of a causal hypothesis being true is the same as of it being false…

- So very strong (weighty) evidence corresponds to either a very high or very low probability of the hypothesis being true.

Probability of hypothesis being true $\psi\,(H{=}T)$

Probability of hypothesis being false $\psi\,(H{=}F)$

Large WOE

WOE = 0

1.0

0.5

0

0   0.5   1.0
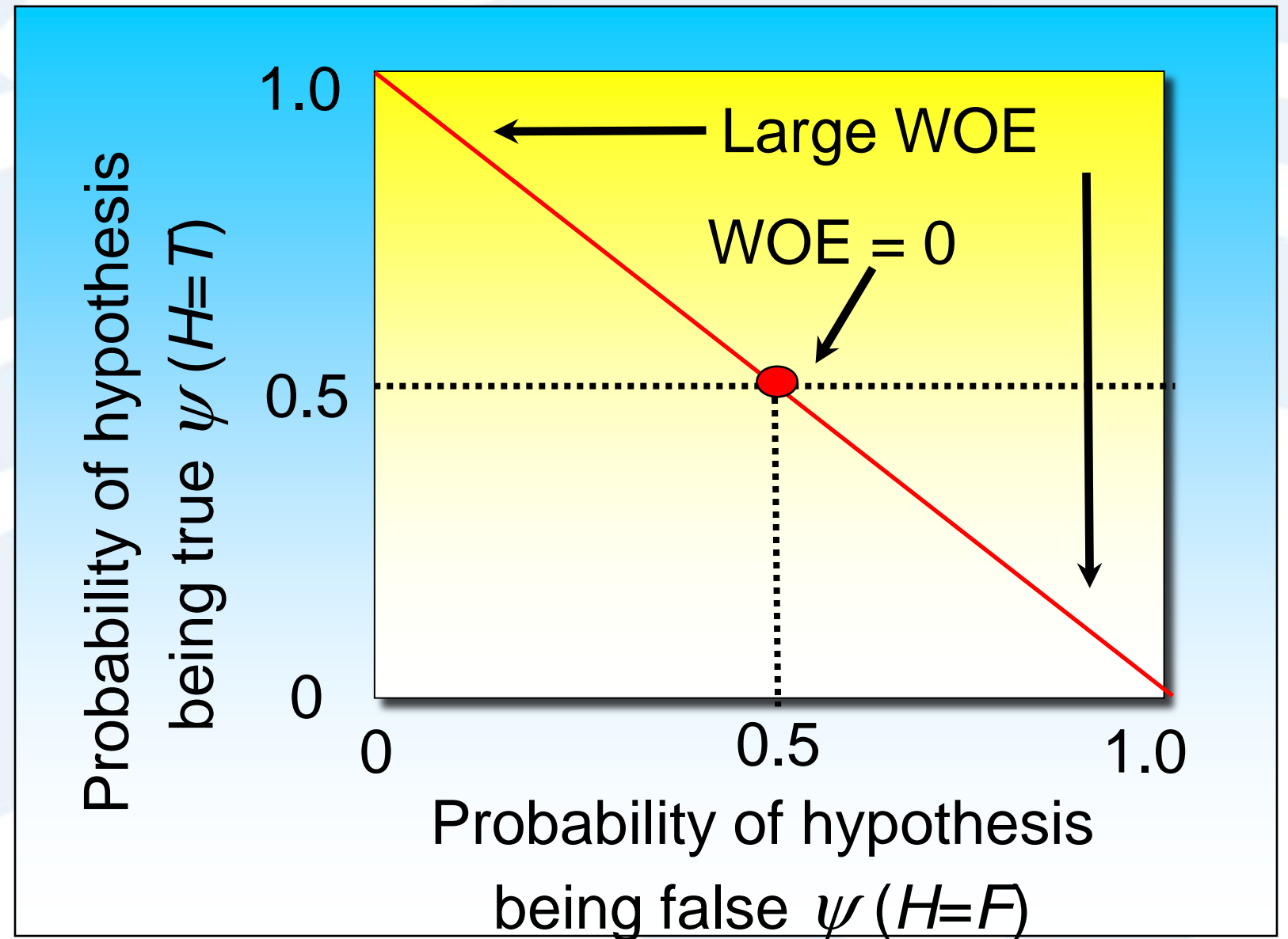
Standards of proof & weight of evidence

- We can relate legal "standards of proof" to the probability of a scientific hypothesis being true, given existing weight of evidence (WOE)
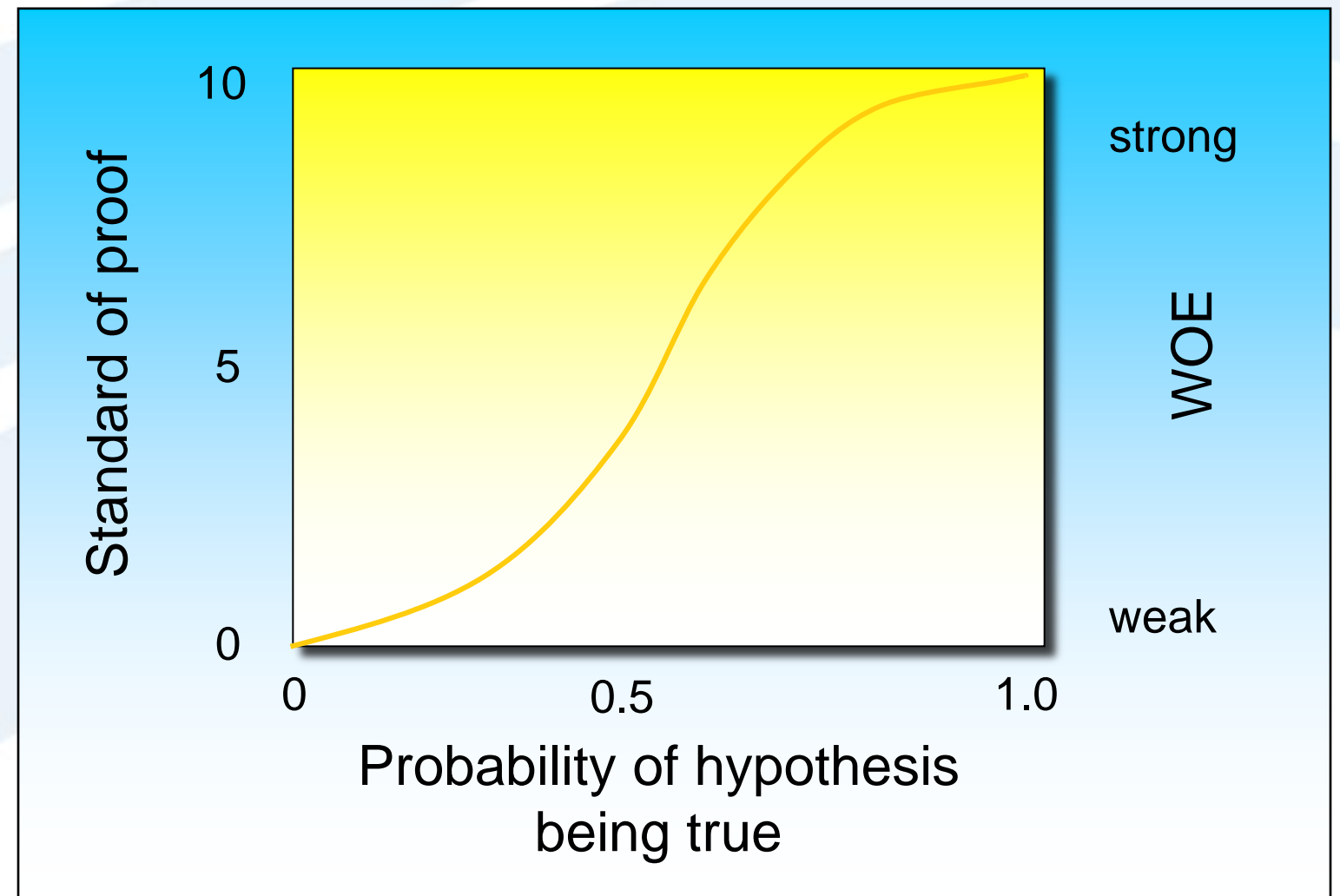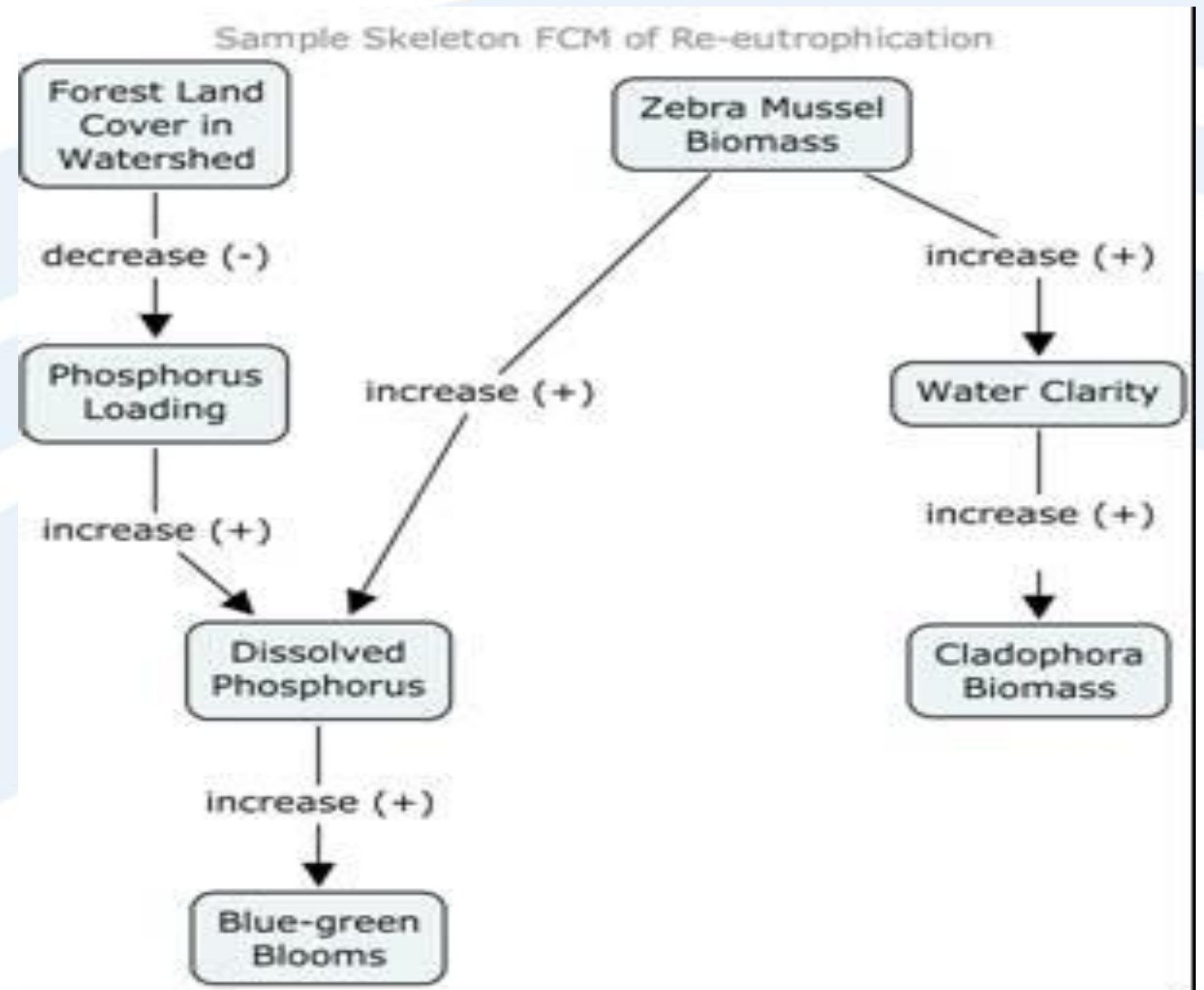
Fuzzy Cognitive Map (FCM)

- A tool for representing the causal structure of a system

- Elements include concepts (vertices) and relationships among concepts (arcs)

- The resulting FCM is (formally) a graph, and can be analyzed using various graph-theoretic techniques.

Sample Skeleton FCM of Re-eutrophication
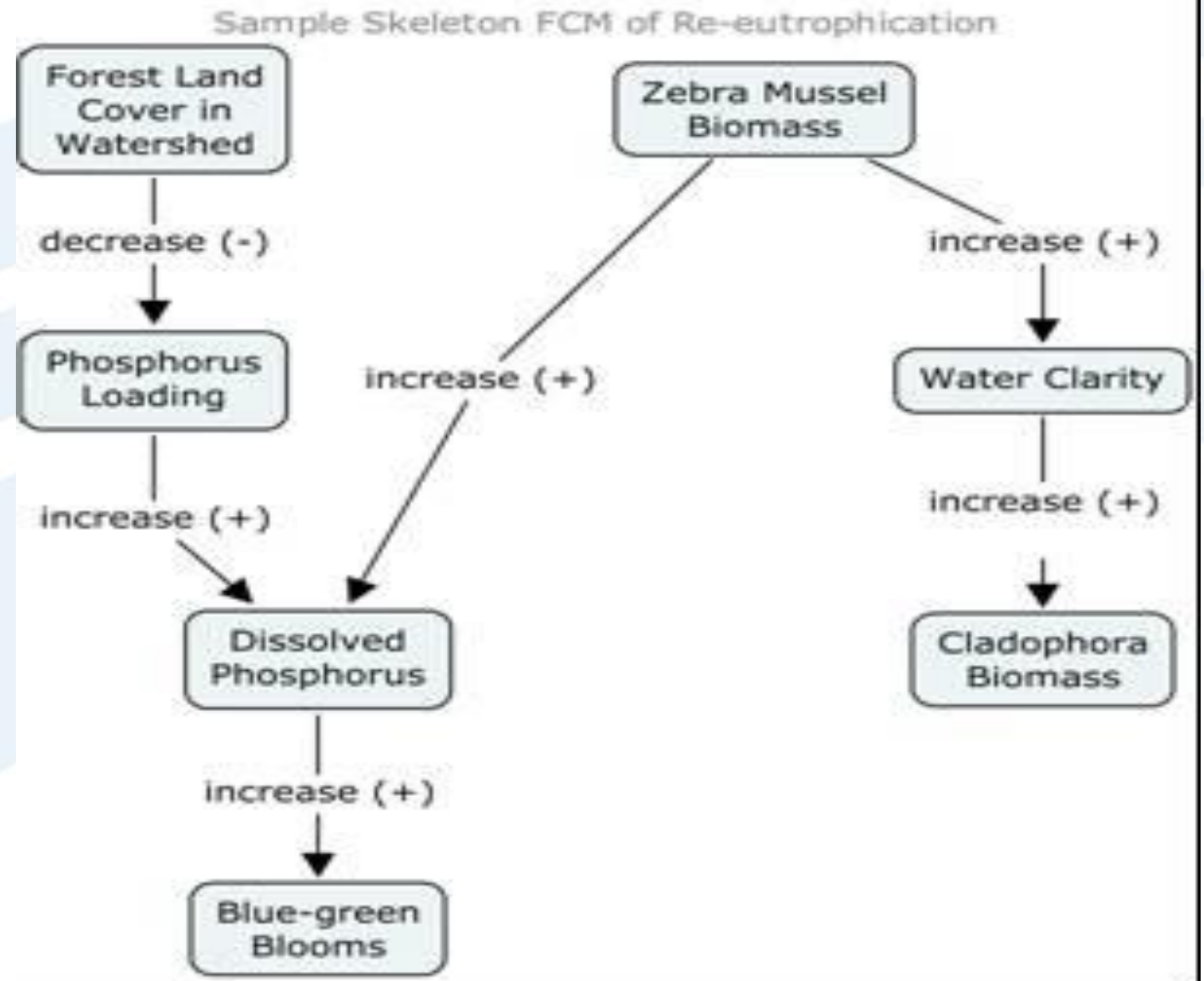
Supporting Information for Arcs

- Label each arc in the map by attributes of evidence

- Attribute classes include:
  - Sign
  - Importance/strength
  - Evidence base
  - Spatial scale
  - Temporal scale
  - Universality
  - Change Feasibility

Sample Skeleton FCM of Re-eutrophication

Forest Land Cover in Watershed → decrease (-) → Phosphorus Loading → increase (+) → Dissolved Phosphorus

Zebra Mussel Biomass → increase (+) → Dissolved Phosphorus

Zebra Mussel Biomass → increase (+) → Water Clarity → increase (+) → Cladophora Biomass

Dissolved Phosphorus → increase (+) → Blue-green Blooms

Participant Maps

- 14 Independent FCMs
- 10 FCMs used for analysis
- 14 to 44 individual concepts
- 9 to 25 directed arcs
- Many common concepts with different names
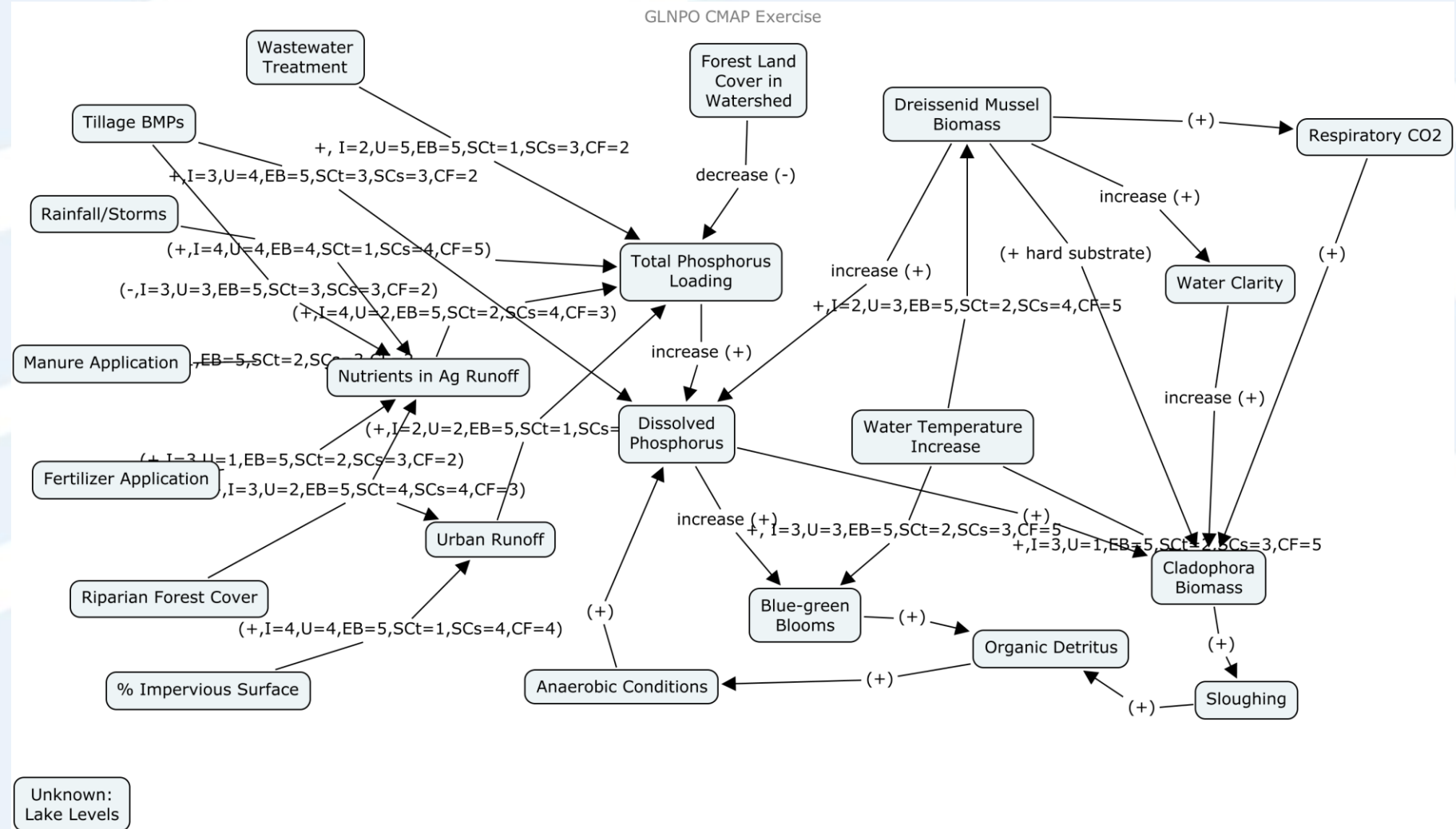
Participant Map
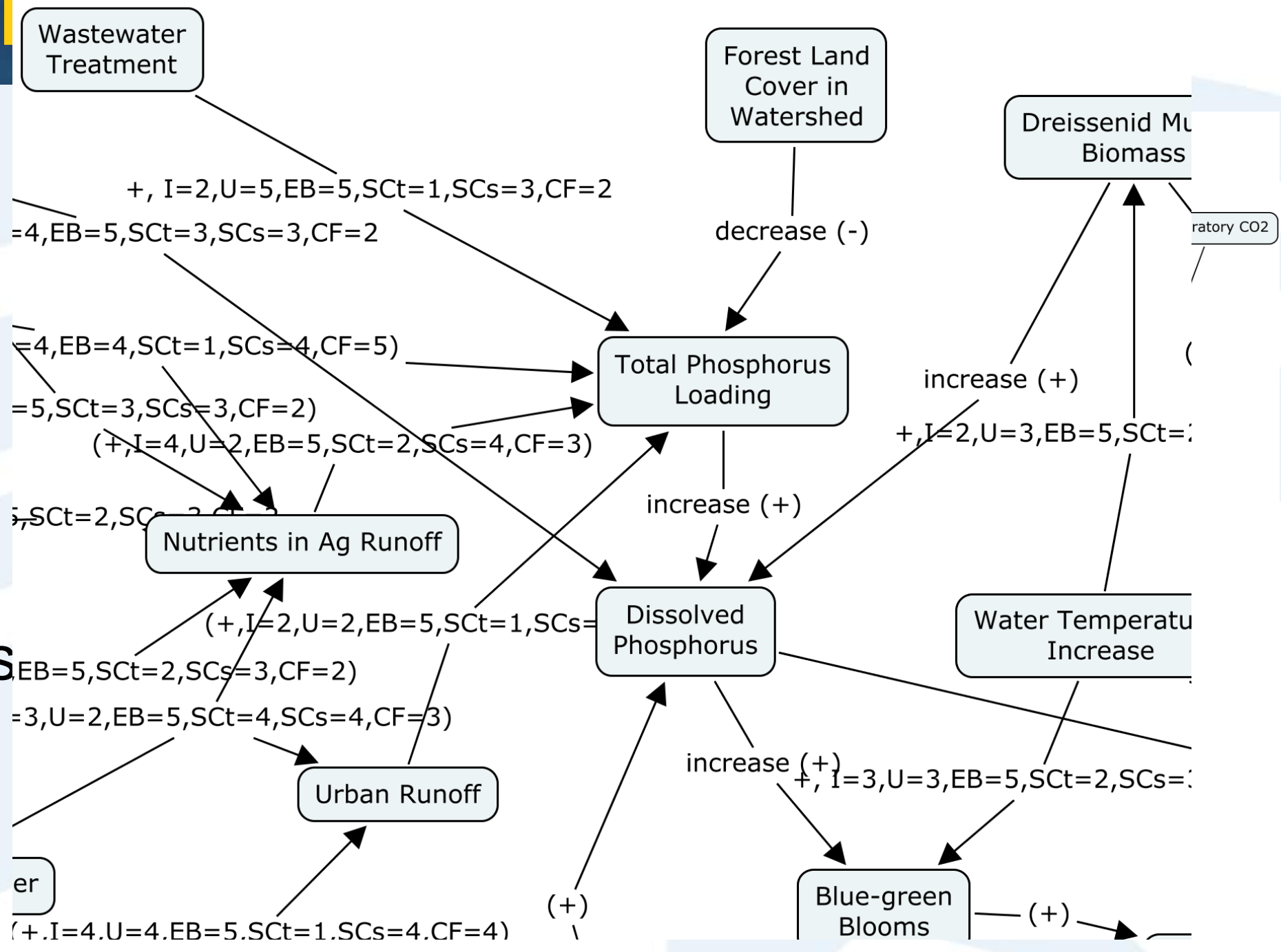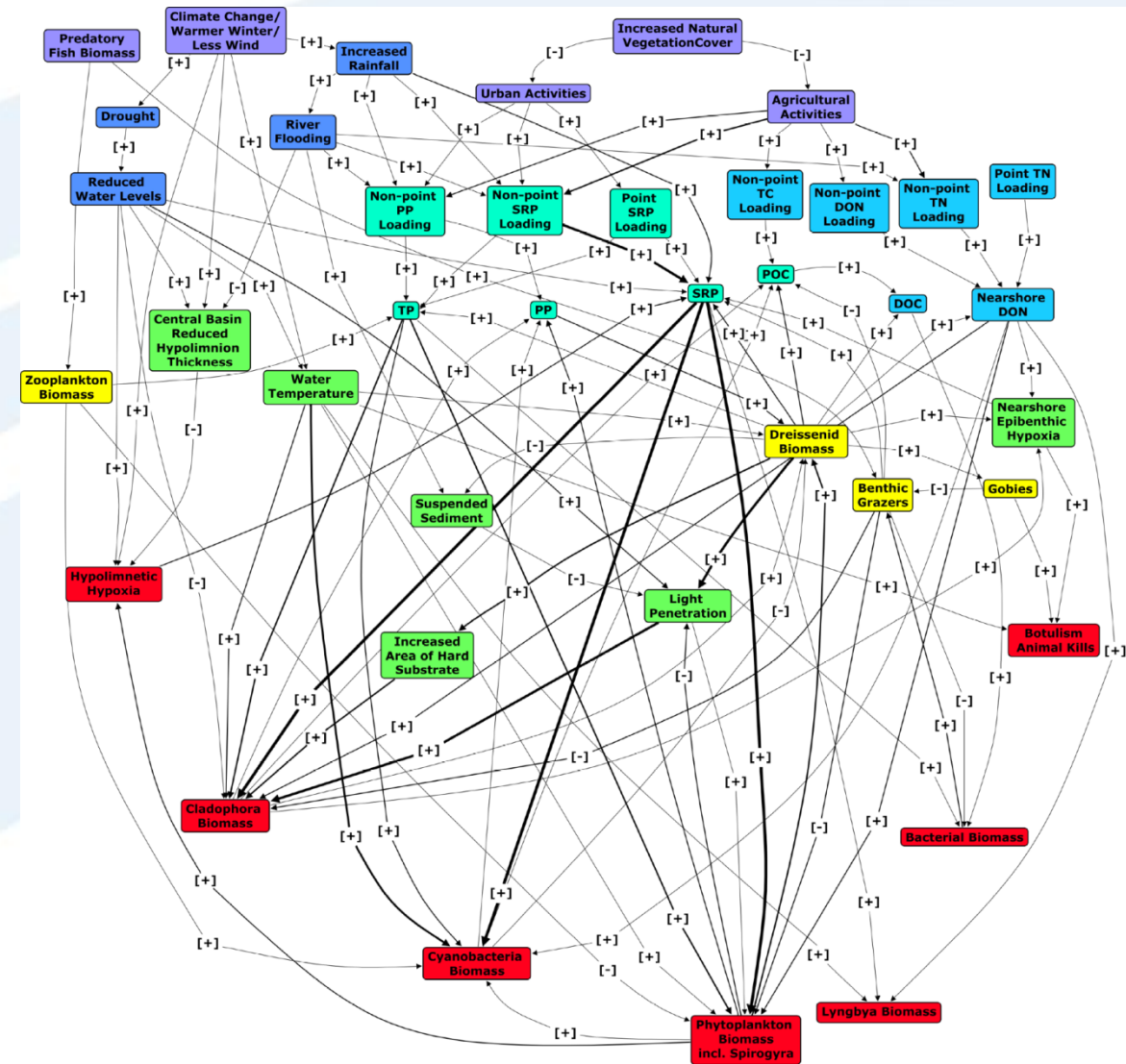
- 14 Independent FCMs
- 10 FCMs used for analysis
- 14 to 44 individual concepts
- 9 to 25 directed arcs
- Many common concepts with different names

Consensus Map—Union of 10 FCMs

- 62 Concepts
- 193 Directed Arcs
- 7 Outcomes of Interest
- 5 Major Emitters
  - Climate Change
  - Fish Predators
  - Urban Activities
  - Agricultural Activities
  - Natural Vegetation

WOE and FCM Linkage

- Using WOE for each arc in all paths connecting a management intervention to an outcome of interest, we can calculate (via transitive closure) the WOE for the path.

- Alternatively, we can estimate consensuality WOE of an arc a(i,j) as the number of maps (out of 10) that have this arc either implicitly OR explicitly.

- Independently we can derive WOE for each arc by determining the extent to which an explicit causal arc a(i,j) is supported by the literature.

Minimal Conditions for Evidence-informed Recommendations by the IJC

- Explicit statement of *all* hypotheses underlying a recommendation.
- At least qualitative (ordinal) assessment of current WOE associated with *each* hypothesis underlying a recommendation.
- Explicit distinction between scientific issues (more objective) and normative issues (less objective) underlying a recommendation
- Explicit statement of threshold WOE required for recommendation.

Findings

- Major re-eutrophication concerns (outcomes of interest):
  - ***Cladophora* biomass,**
  - **Cyanobacteria biomass,**
  - phytoplankton biomass,
  - central basin reduced hypoliminion thickness,
  - hypolimnetic hypoxia,
  - botulism animal kills,
  - *Lyngbia* biomass and *Spirogyra* biomass
- Dominant causal concepts (those concepts with a large number of causal inputs and/or outputs):
  - nearshore soluble reactive phosphorous,
  - *Cladophora* biomass and
  - Dreissenid biomass.

Findings

- Major emitters (concepts which affects other concepts, but are not themselves affected by other concepts in the consensual map):
  - climate change,
  - predatory fish biomass,
  - urban activities,
  - agricultural activities, and
  - natural vegetation cover
- Weak WOE supporting linkage of these drivers and indicators of re-eutrophication
- Lack of clarity about contributions of physical factors (e.g. water depth, climate, nearshore habitat) to re-eutrophication symptoms

Policy and Management Challenges—Management Under Uncertainty

- Weight of scientific evidence is equivocal about the efficacy of reductions in phosphorus loading to mitigate reemerging symptoms of eutrophication
- "No regrets" management options could be helpful
  - In urban areas, reducing P discharges by optimizing STP operations at facilities located in P sensitive watersheds
  - In rural areas, promoting soil and water conservation BMPs to increase infiltration and reduce runoff and loss of soil may enhance efforts to control nuisance conditions in watersheds which are priority for eutrophication concerns

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