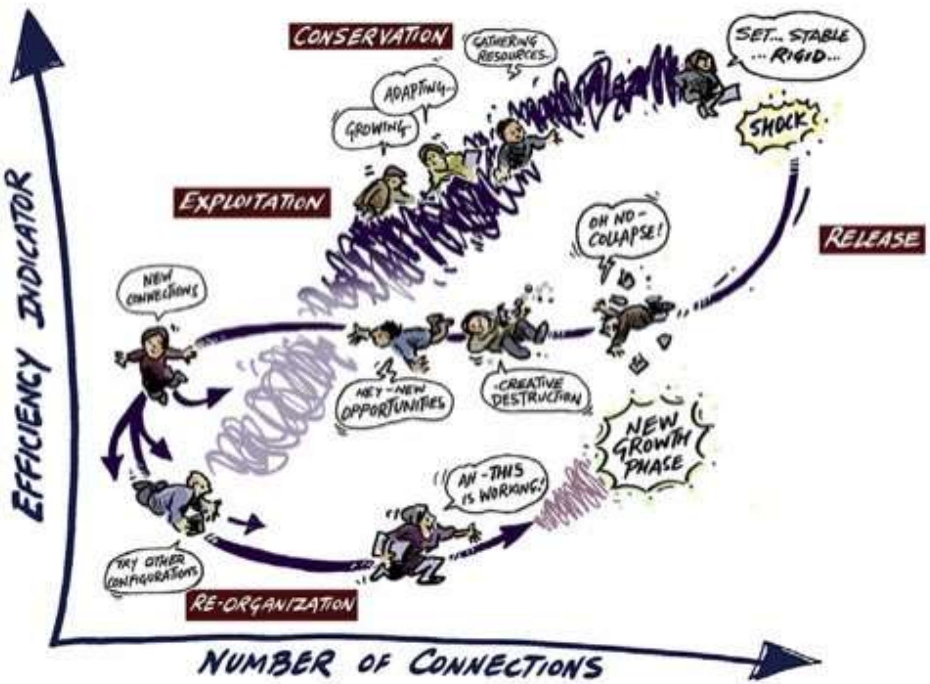
Resilience in Social-Ecological Systems: Models and Field Studies



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Topics

Brief history of resilience for social-ecological systems

Economics as a basis for SES modeling

Exploring the backloop

RAYS (Resilience Alliance Young Scholars) synthesis

Field-testing ideas about resilience

Summary

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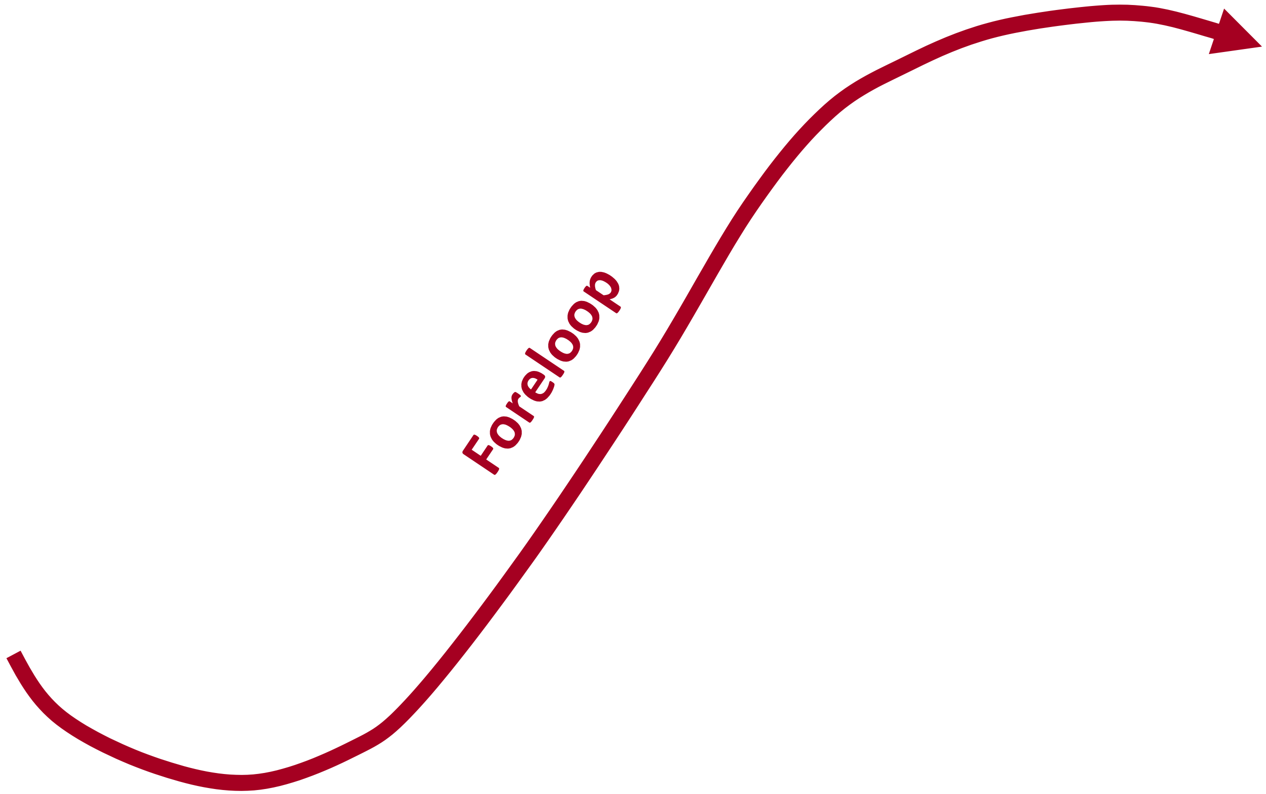
Resilience Network 1995-2000

Resilience Alliance 2000 – present

Stockholm Resilience Centre 2008 – present

Routine Change



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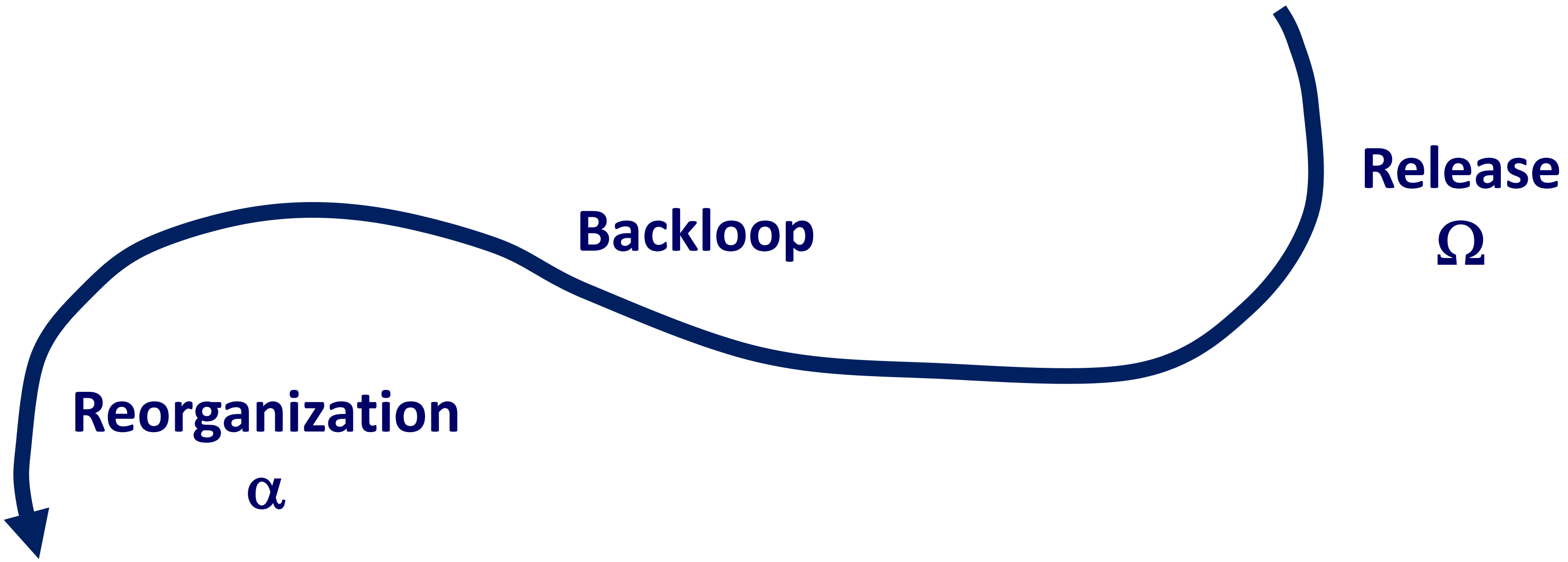
Turbulent Change



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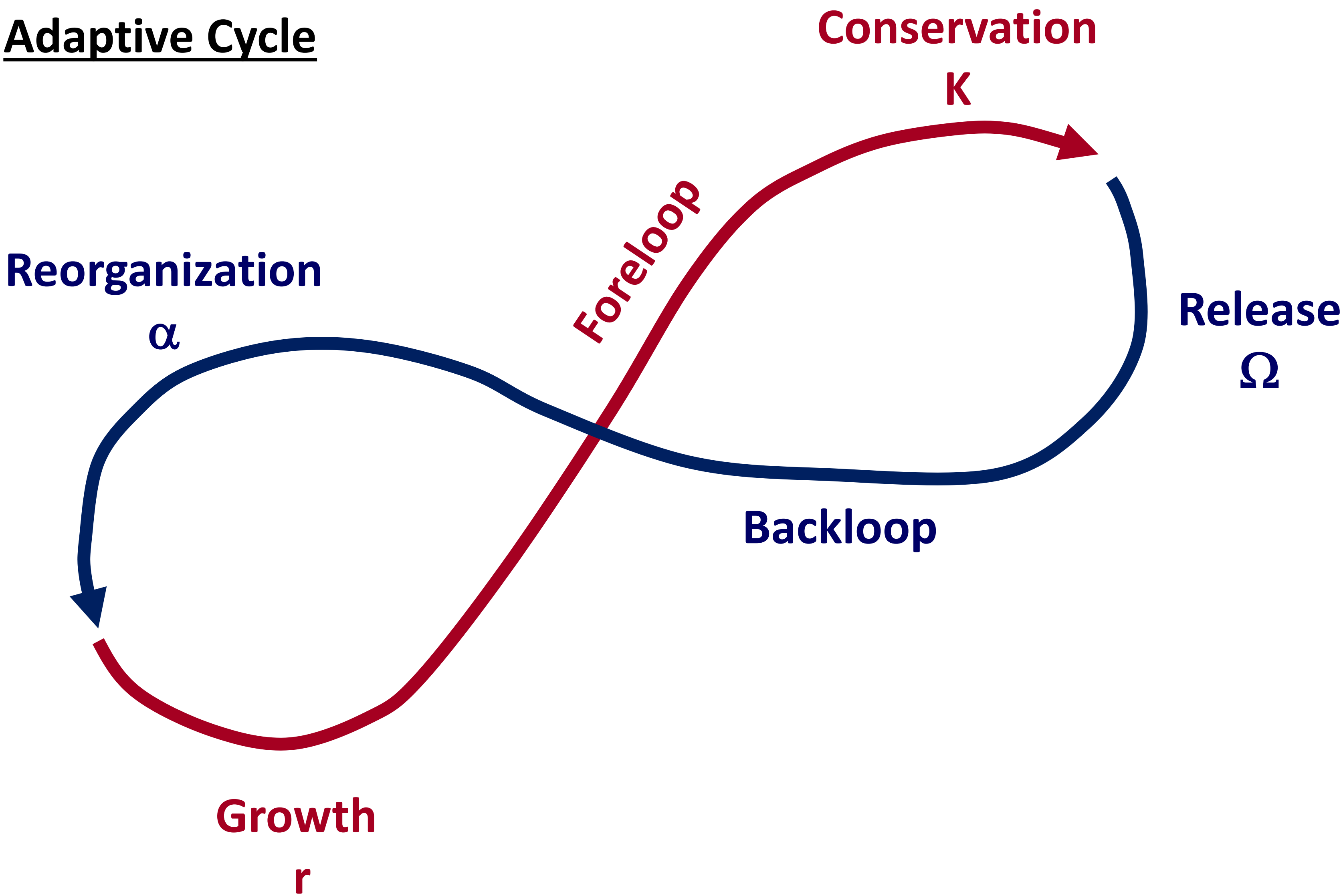
Adaptive Cycle



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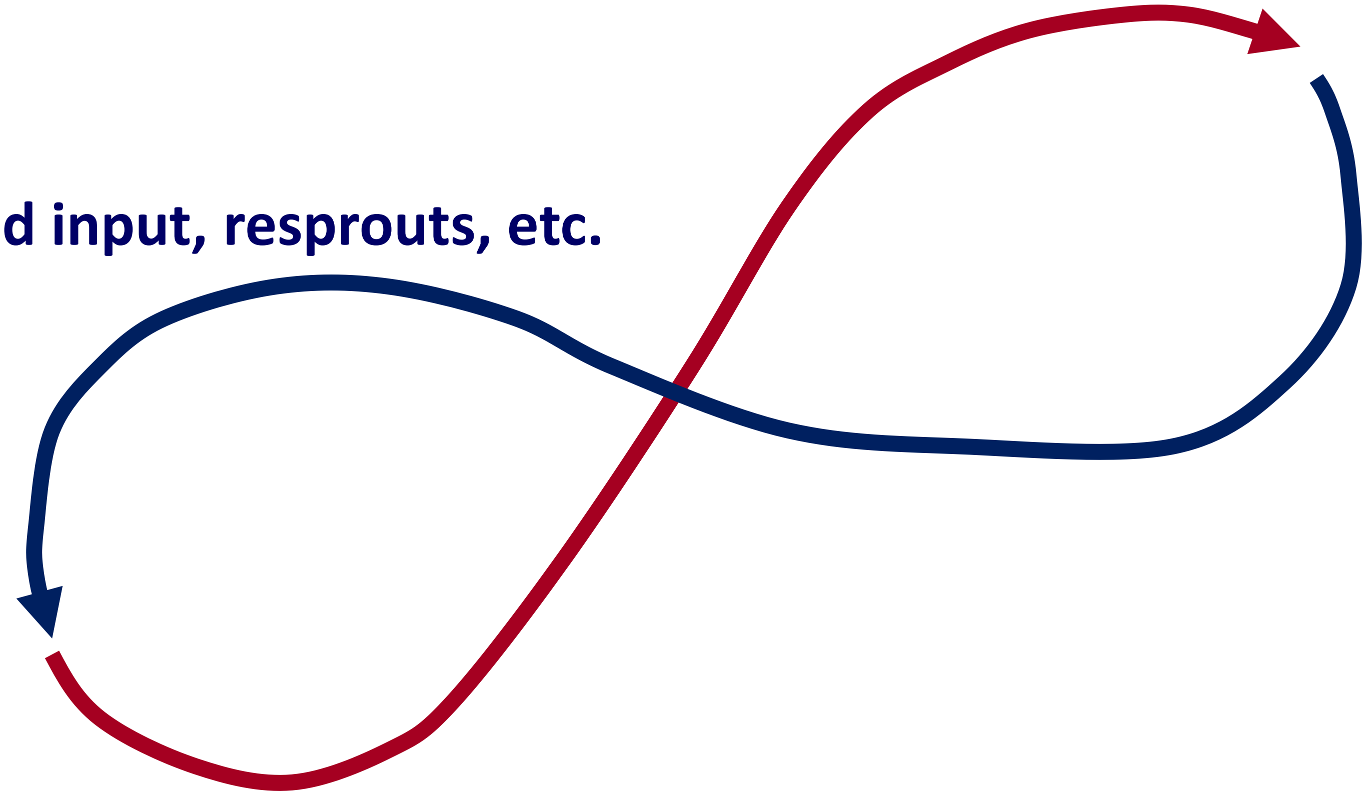
Example: Forest Fire

K: Old trees, closed canopy,
many dead trees & branches

α: seed input, resprouts, etc.

Ω: Fire



r: young trees,
open canopy,
low fuel

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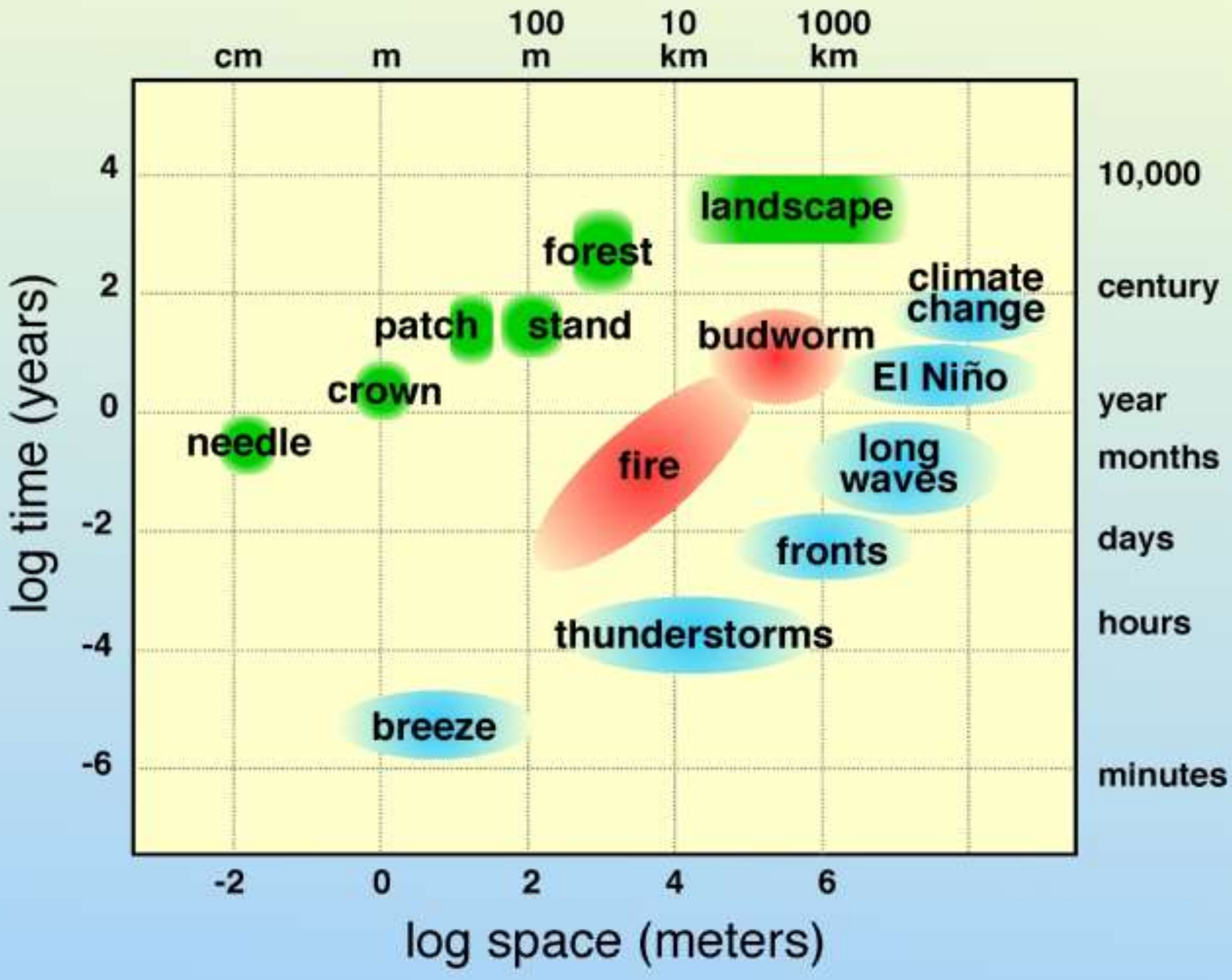
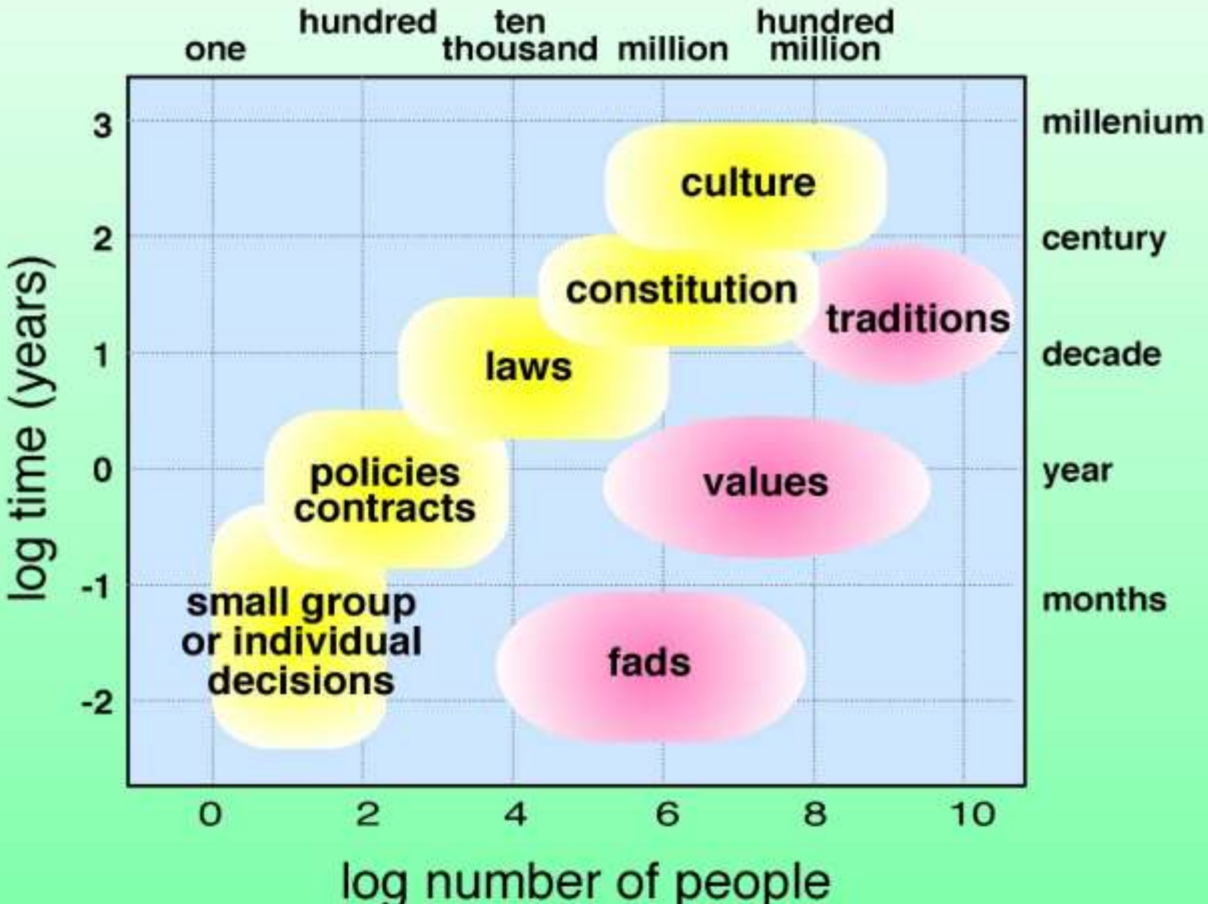
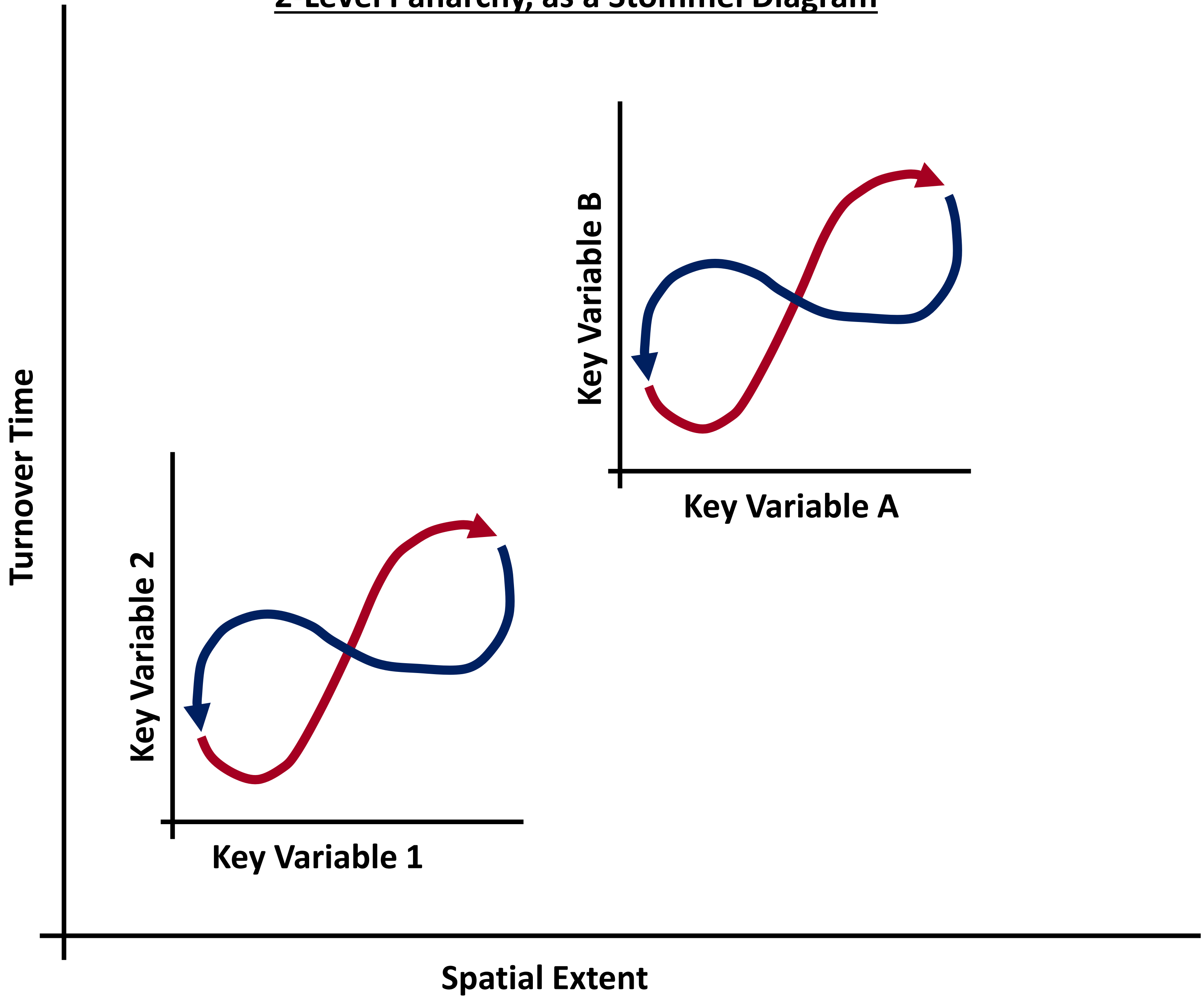

cm
m
100 m
10 km
1000 km
4
2
0
-2
-4
-6
10,000
century
year
months
days
hours
minutes
landscape
forest
climate change
patch
stand
budworm
crown
El Niño
needle
fire
long waves
fronts
thunderstorms
breeze
-2
0
2
4
6
log time (years)
log space (meters)


one
hundred
ten thousand
million
hundred million
3
2
1
0
-1
-2
millenium
century
decade
year
months
culture
constitution
traditions
laws
policies contracts
values
small group or individual decisions
fads
0
2
4
6
8
10
log time (years)
log number of people

2-Level Panarchy, as a Stommel Diagram



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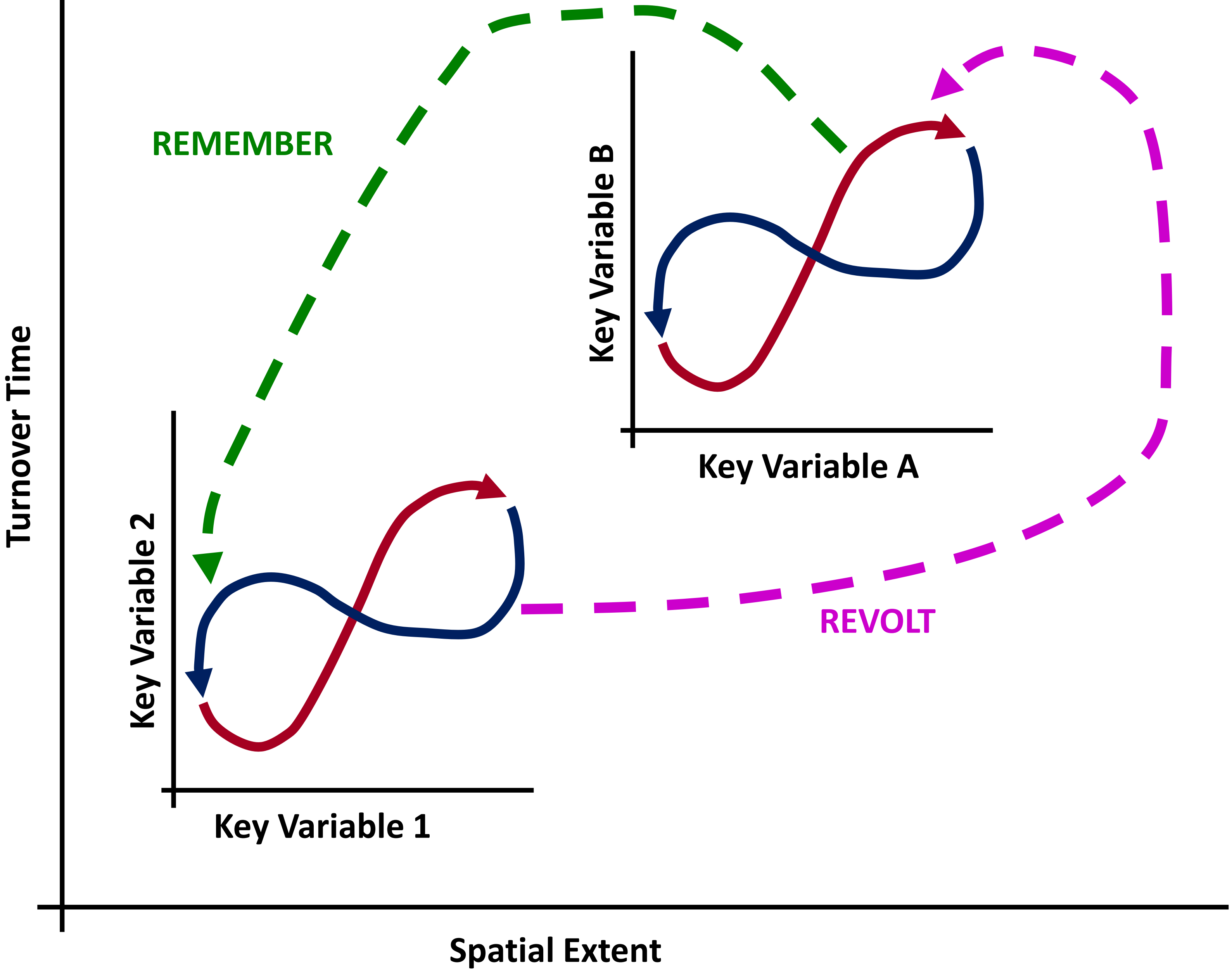
Cross-Scale Interaction in a Panarchy



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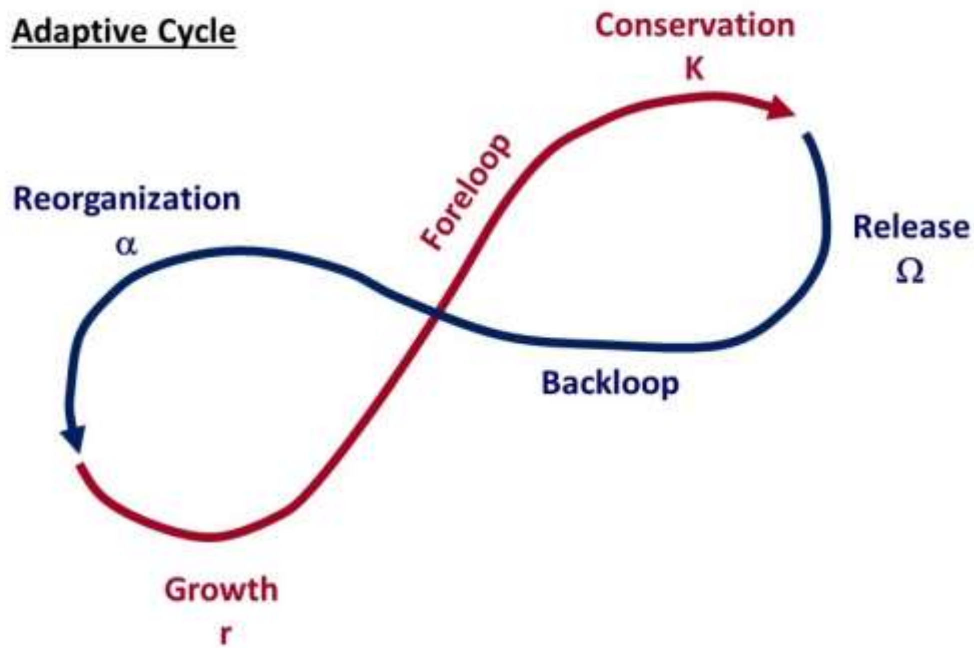
Change in Organizations

Frances Westley leads workshop, Montevideo, Uruguay 2015

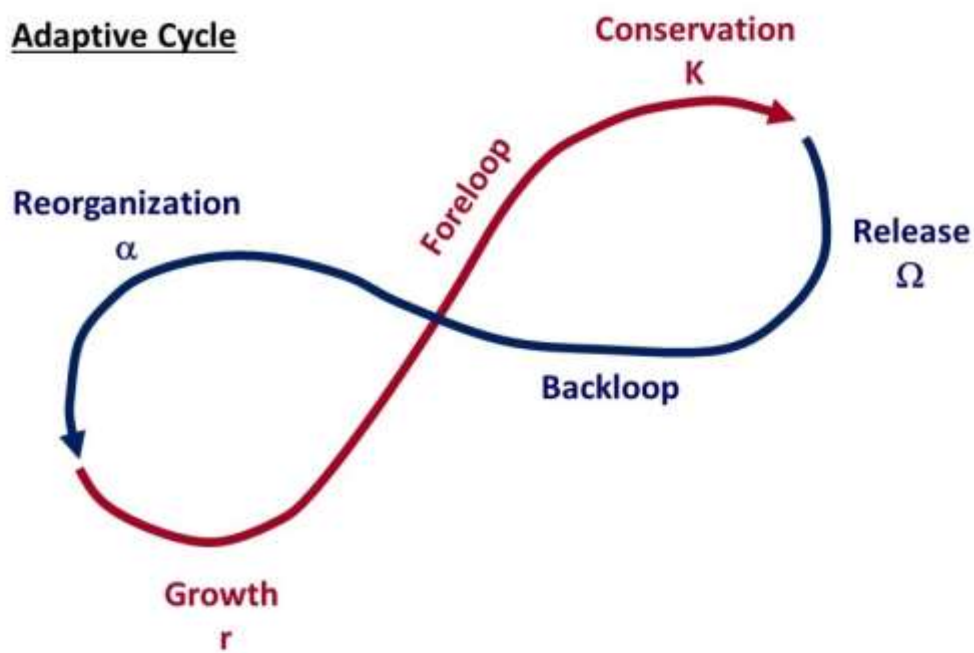


Growth or Exploitation

Trigger: People converge
(on approach, process, product, question etc.)

People: engineers, implementers, organizers, team-builders

Experience: excitement, flow, high energy, rapid learning, progress

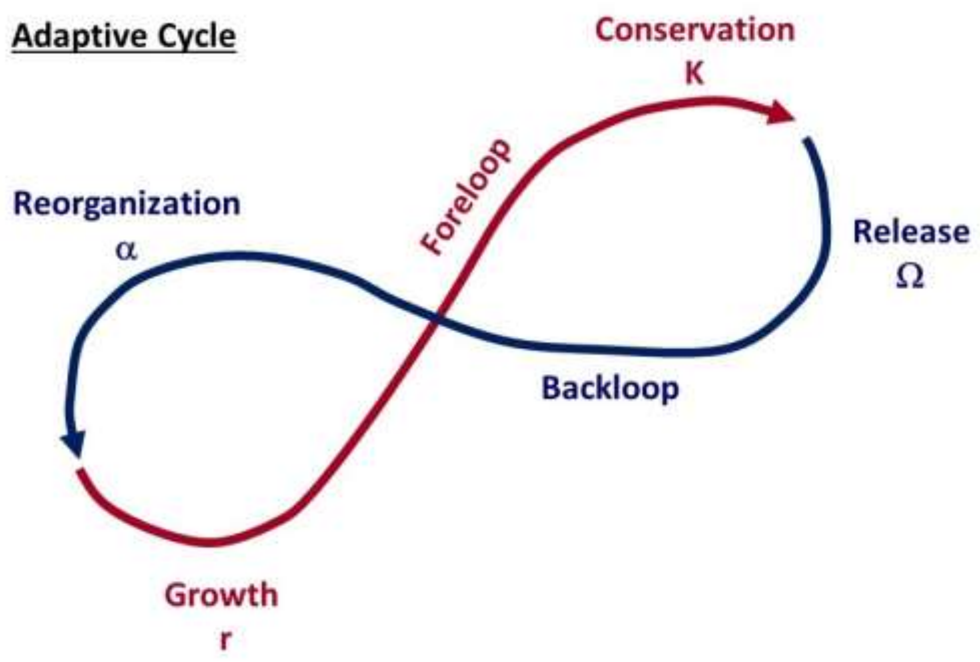


Conservation

Trigger: Near peak production and efficiency; incremental progress.

People: engineers, managers. Innovators may be a bit bored.

**Experience: satisfaction, pride of accomplishment;
anxiety about growing stresses and loss of momentum.**

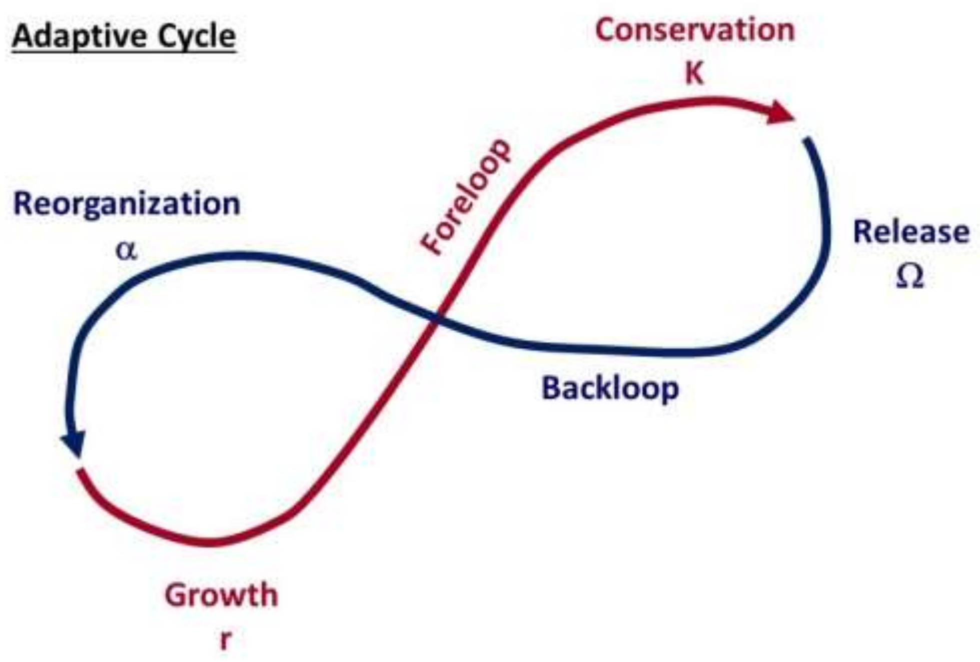


Release

Trigger: Discontinuation or breakdown of key processes.

People: Those who thrive on crisis are excited.
Others may mourn losses.

Experience: anxiety, changing relationships, confusion, elation, identity crisis.



Reorganization

Trigger: Need for innovation. Meandering, loss of focus, experiments that may have few measurable outcomes for some time

People: Those who love to play with uncertainty are happy here; entrepreneurs and innovators

Experience: false starts, frustration, occasional breakthrough

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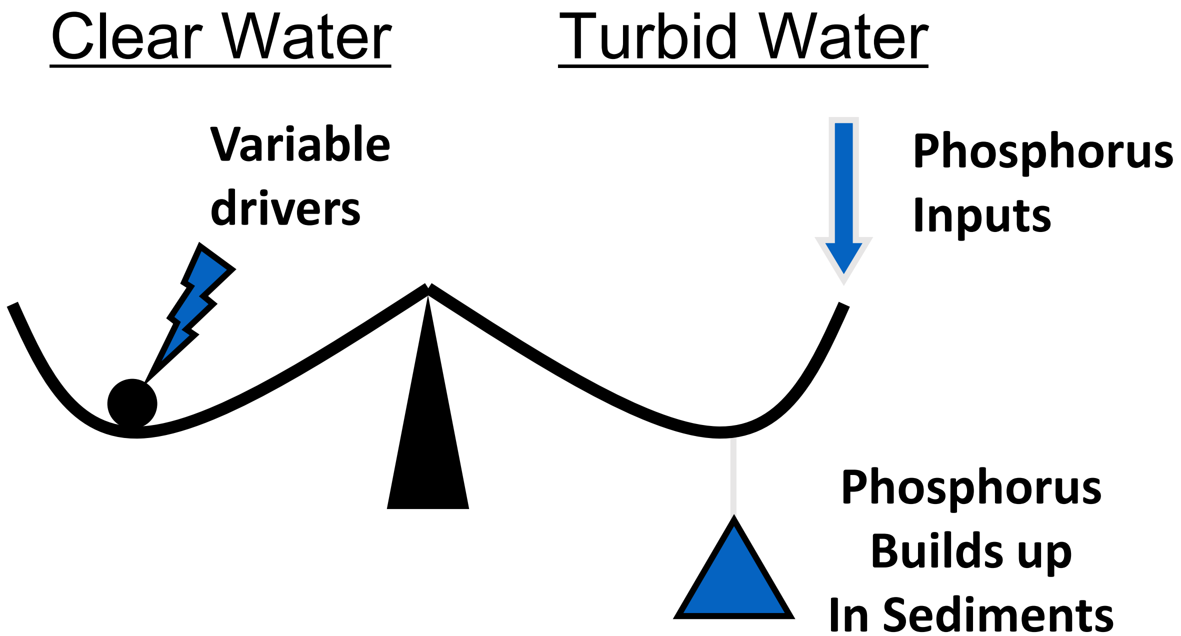
Economic Analyses of Critical Transitions

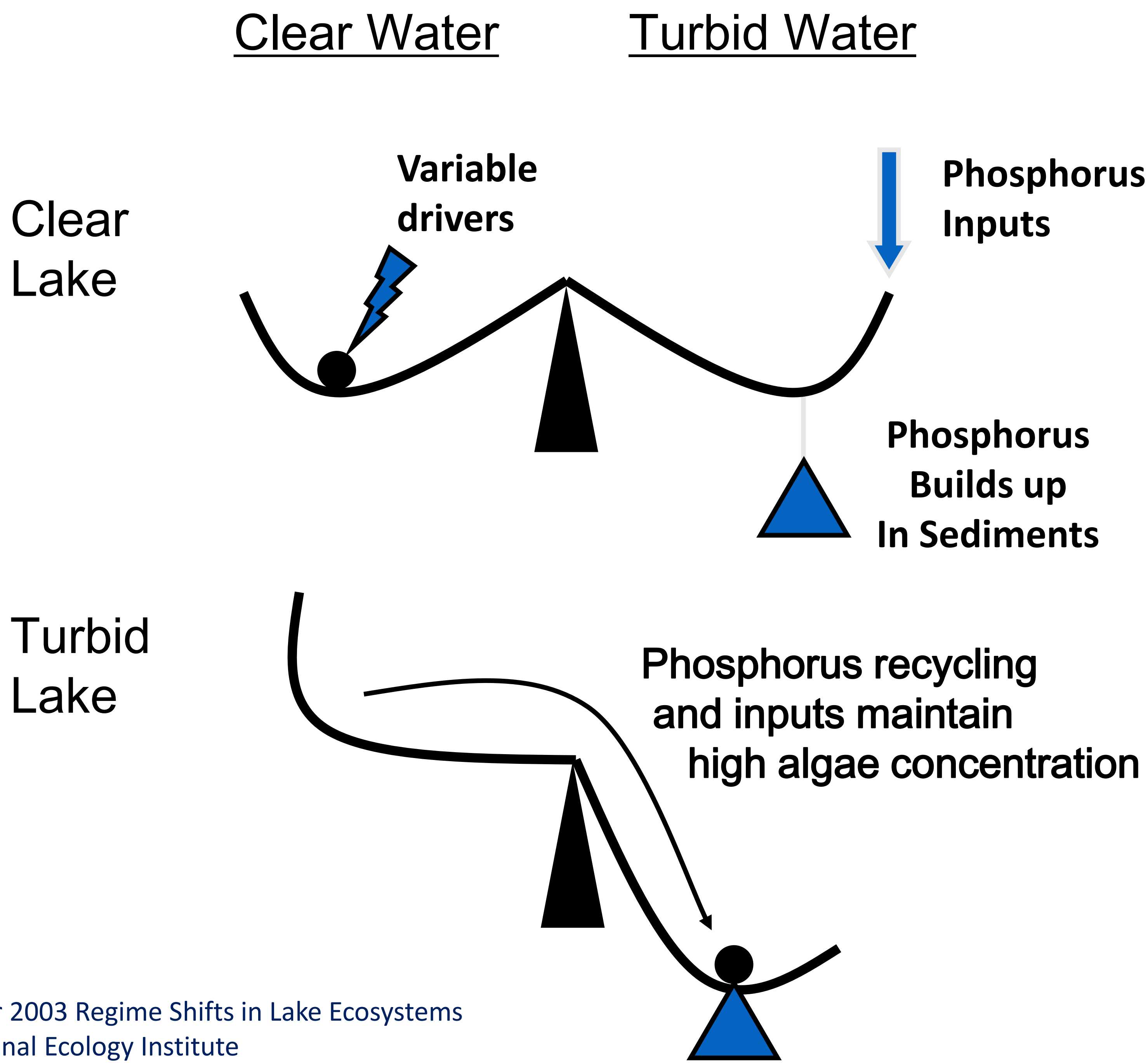
What is the optimal level of pollutant loading for an ecosystem with a threshold?



Carpenter, Ludwig, Brock. 1999. Ecological Applications 9: 751-771.

Ludwig, Carpenter, Brock. 2003. Ecological Applications 13: 1135-1152.

Ludwig, Brock, Carpenter. 2005. Ecology & Society 10(2), article 13.



Carpenter 2003 Regime Shifts in Lake Ecosystems
International Ecology Institute

Economic Analyses of Critical Transitions

General pattern:

The Optimal Policy adds just enough pollutant to avoid crossing the threshold.

Mistakes will be made.

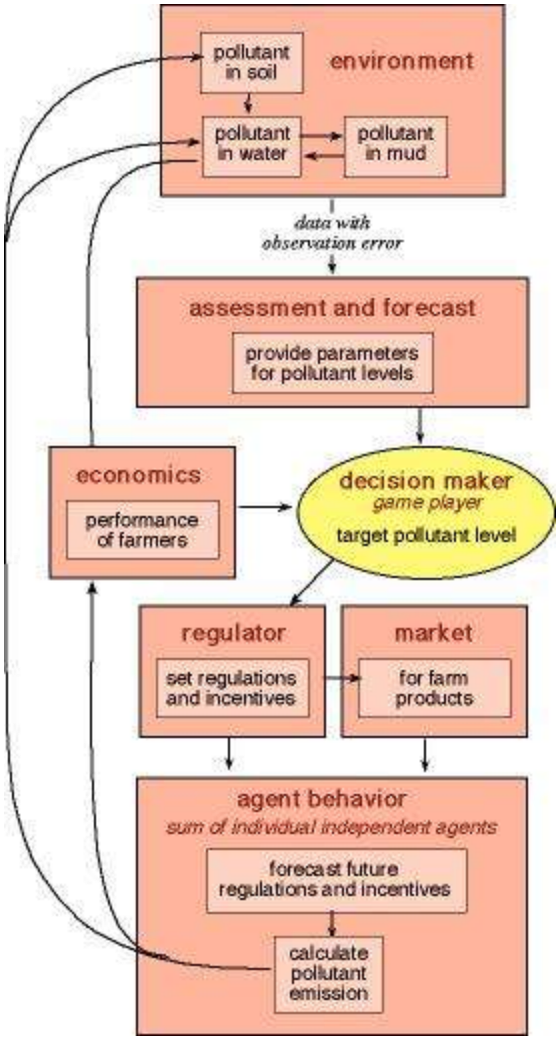
Backloops will happen.

Carpenter, Ludwig, Brock. 1999. Ecological Applications 9: 751-771.

Ludwig, Carpenter, Brock. 2003. Ecological Applications 13: 1135-1152.

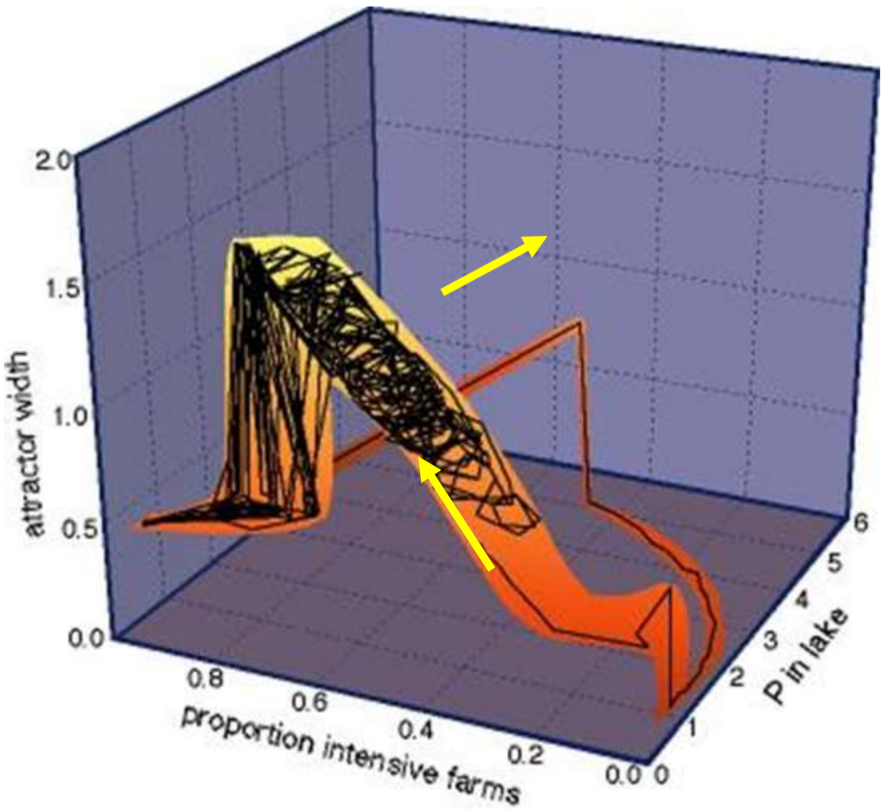
Ludwig, Brock, Carpenter. 2005. Ecology & Society 10(2), article 13.

Social-Ecological Models of Ecosystem Management



"Agents" and regulator make decisions based on rational expectations & information available to them

Nonlinear ecosystem dynamics respond to human action and are measured imperfectly by agents & regulator.



Carpenter, S.R., W.A. Brock and P.C. Hanson. 1999. Ecological and social dynamics in simple models of ecosystem management. Conservation Ecology 3(2): 4. URL: http://www.consecol.org/vol3/iss2/art4

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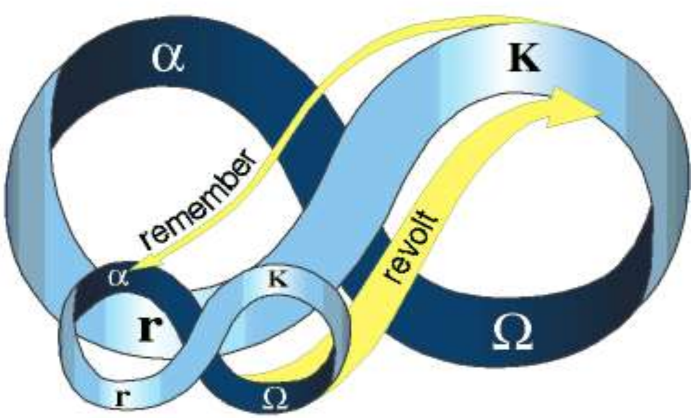
What to do in the Backloop?

Protect the experience needed for wisdom

Stimulate innovation in safe-to-fail experiments

Build capacity to adapt to change

Expand and communicate understanding of change



Scenarios

are plausible stories about
how the future of a social-ecological system might unfold
from existing patterns, new factors, and
alternative human choices.

(Paul Raskin, 2005, in *Ecosystems*)

[Plot is]

**“the gradual perturbation of
an unstable homeostatic system and
its catastrophic restoration to
a new and complexified equilibrium”.**

**(John Barth, quoted by Jennifer Boylan,
NYTBR 10 April 2016)**

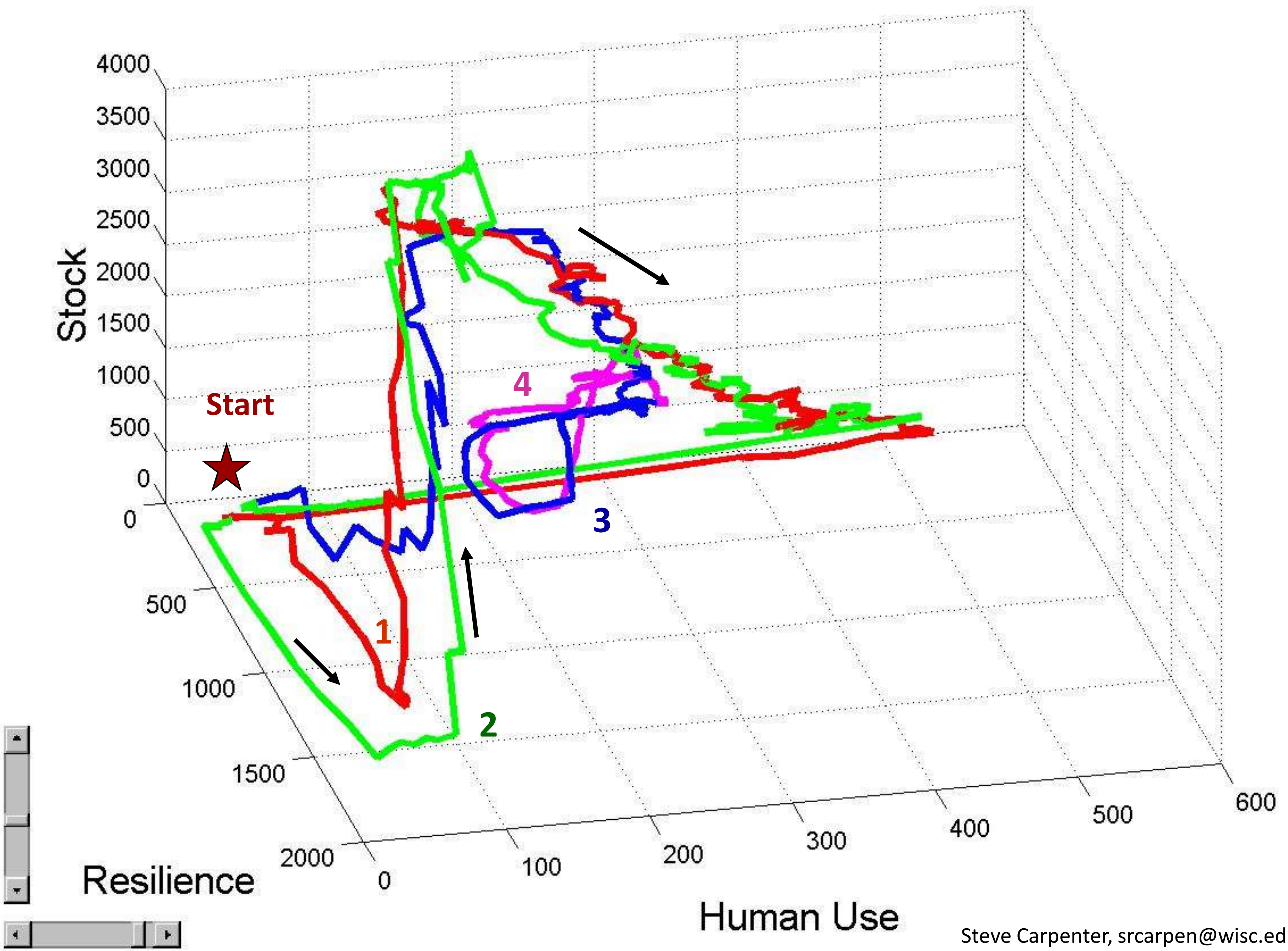
Northern Highland Lake District, Wisconsin






Workshops, Scenarios, Games
2000-2002

Four Cycles in the Northern Highland Adaptive Management Game



Carpenter, 2002, Ecology 83: 2069-2083

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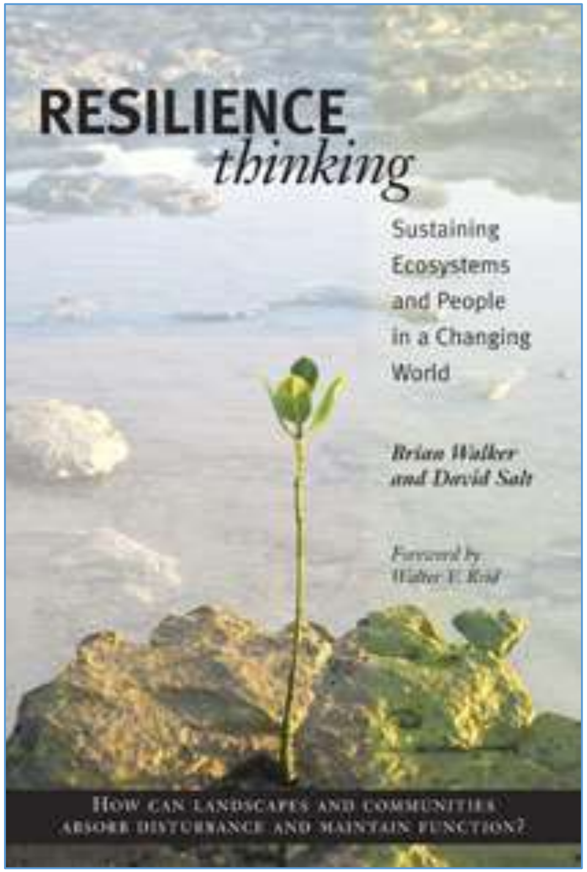
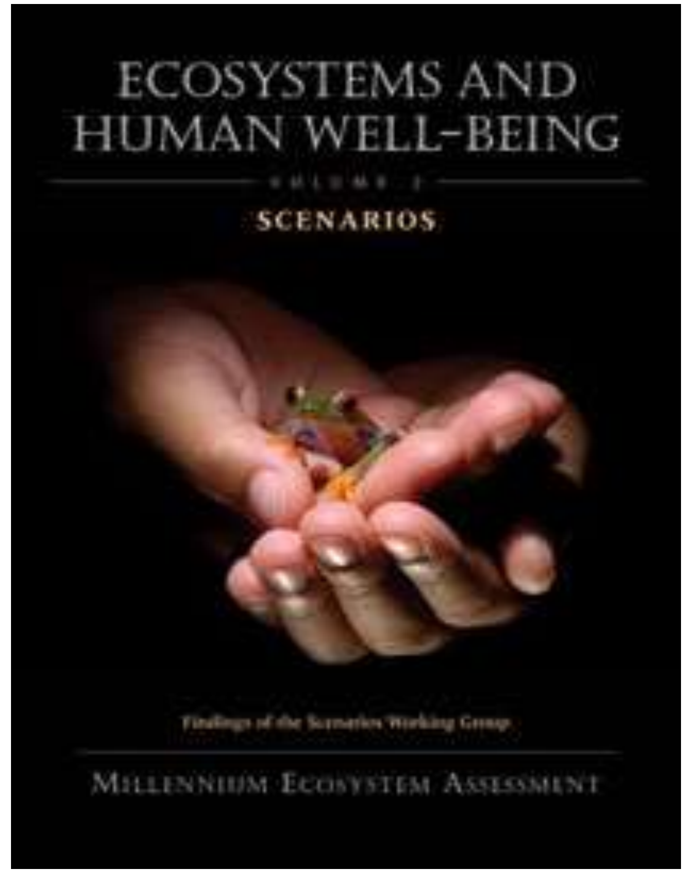
Two Big Attempts to Integrate Science and Stakeholders for Ecosystem Management



Case Studies in Applied Resilience
2006
Walker & Salt



Millenium Ecosystem Assessment Scenarios
2005
Carpenter and 96 others

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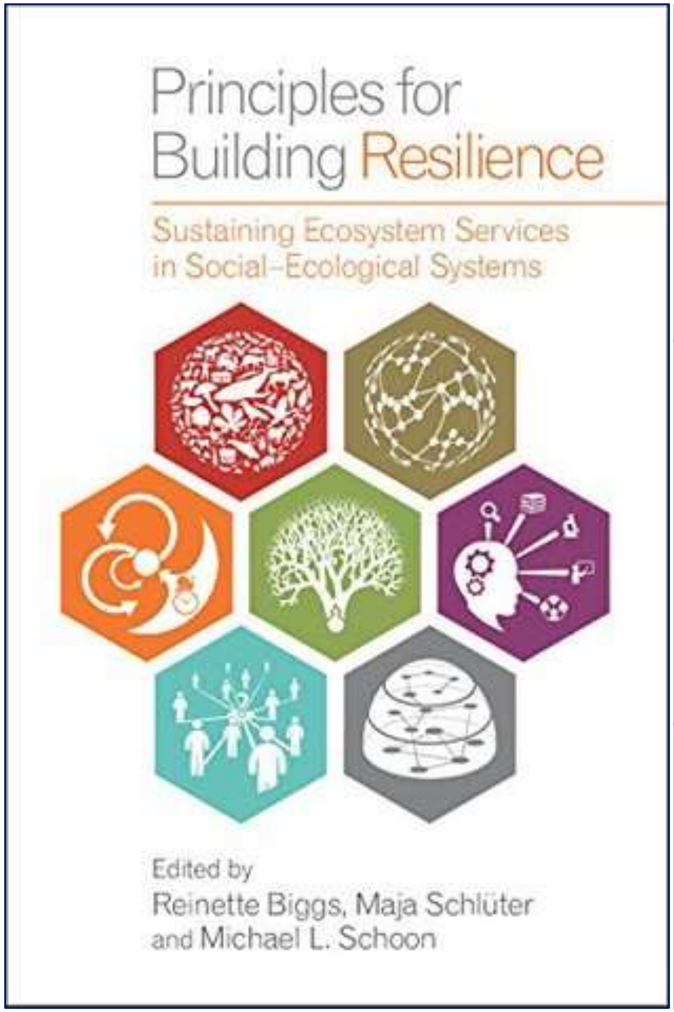
New Synthesis by Resilience Alliance Young Scholars (RAYS) group



Cambridge Univ. Press, 2015

Also see: Biggs et al. 2012. Toward principles for enhancing the resilience of ecosystem services. Ann. Rev. Env. Resour. 37: 421-448.

Maintain Heterogeneity

The point: Different types of ecosystems, cultures, institutions and knowledge systems provide options for responding to change

Heterogeneity is guaranteed to improve resilience if (1) there is a 'central limit' effect that dampens fluctuations and (2) the improvement in resilience diminishes with more of each type.*

How to do it: Conserve heterogeneity; Focus less on maximum efficiency even if it costs more

*Page, S.E. 2011. *Diversity & Complexity*. Princeton Univ. Press, N.J.

Manage Connectivity

The point: Connectivity aids recovery after disturbance, but highly connected systems can spread disturbances faster.

How to do it: Map nodes and connections; Know where to intervene if connectivity needs to be built or broken.

Manage Slow Variables

The point: Gradual drift in slow variables can lead to regime shifts that are long-lasting and expensive to reverse.

How to do it: Monitor slow variables and use governance systems that respond to monitoring information. Strengthen feedbacks that maintain desirable system structure.

Foster Complex Adaptive Systems Thinking

The point: In order to maintain natural resources we need to understand the complex interactions that occur between people and ecosystems.

How to do it: Employ a systems perspective; Investigate critical thresholds; match institutions to key ecological processes; address barriers to cognitive change; expect the unexpected.

Encouraging Learning

The point: Knowledge is always partial, and the system is always changing so the value of existing information decays. Efforts to manage therefore require continual experimentation and learning.

How to do it: Monitor, and use the data to understand change; engage diverse participants and seek opportunities to share knowledge; seek opportunities for adaptive management.

Broaden Participation

The point: Relationships and trust among all key actors are needed to establish legitimacy of knowledge and authority in collective problem-solving processes.

How to do it: Obtain sufficient resources for wide participation; get the right people; recruit inspired and motivated leaders; clarify goals and expectations; deal with power issues and conflicts.

Promote Polycentric Governance

polycentric → multiple institutions interact to make & enforce rules

The point: Emerging problems could be addressed by the right institution at the right scale

How to do it: No simple guidelines

Barriers: Costs of negotiating trade-offs among multiple institutions; it is harder to get agreement for adaptive management; special interests seek out the level of governance most friendly to their narrow goals.

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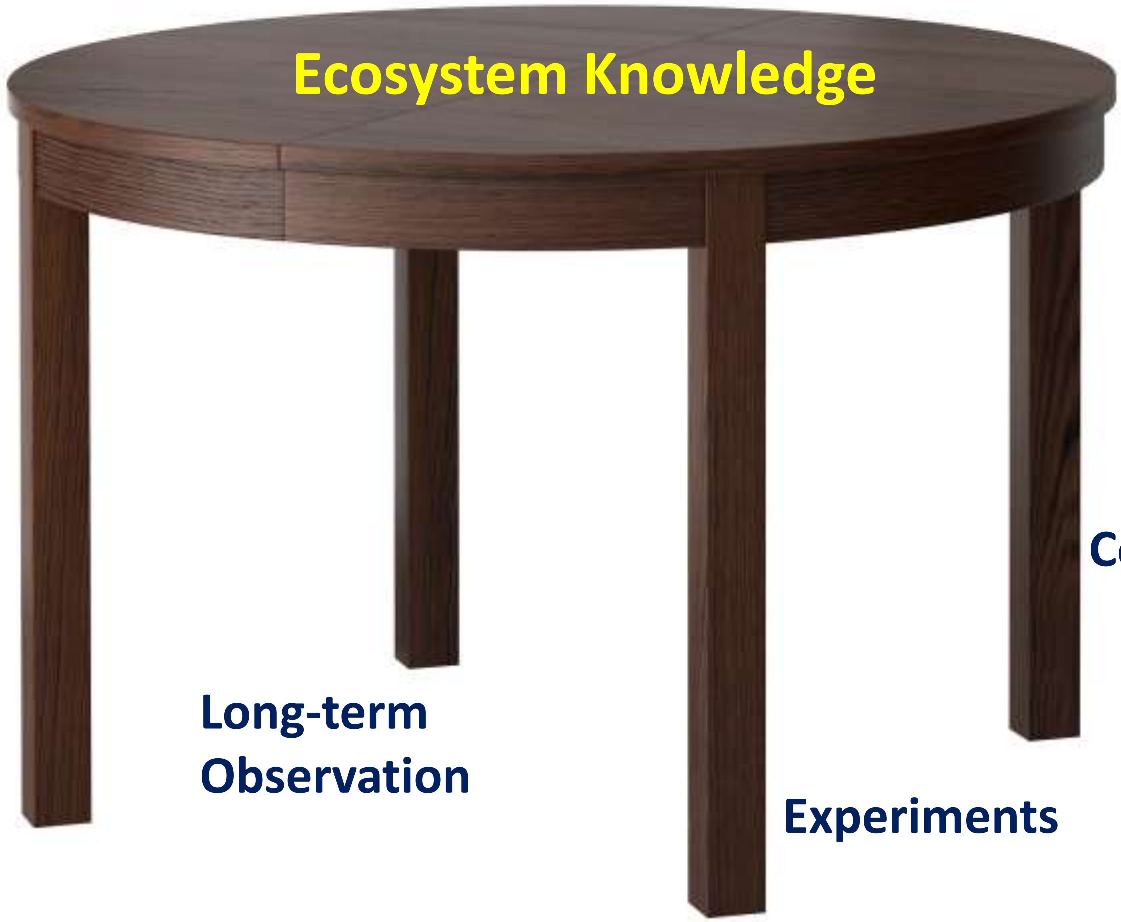
How to Learn about Ecosystems



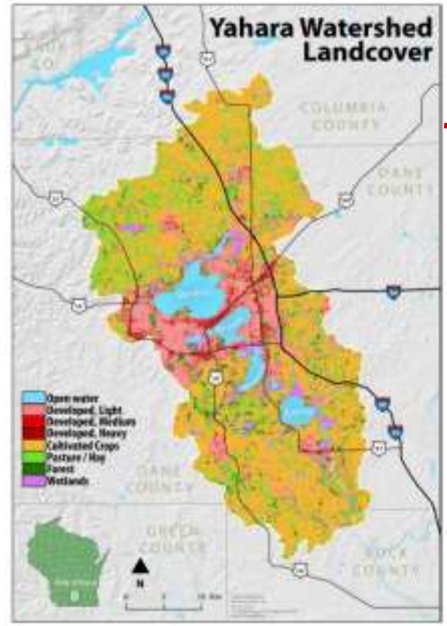
Carpenter, S.R. 1998. The need for large-scale experiments to assess and predict the response of ecosystems to perturbation. pp. 287-312 in M.L. Pace and P.M. Groffman (eds.), Successes, Limitations and Frontiers in Ecosystem Science. Springer-Verlag, N.Y.

To find out what happens to a system when you interfere with it you have to interfere with it (not just passively observe it).

— George E.P. Box
Use and Abuse of Regression (1966), 629.

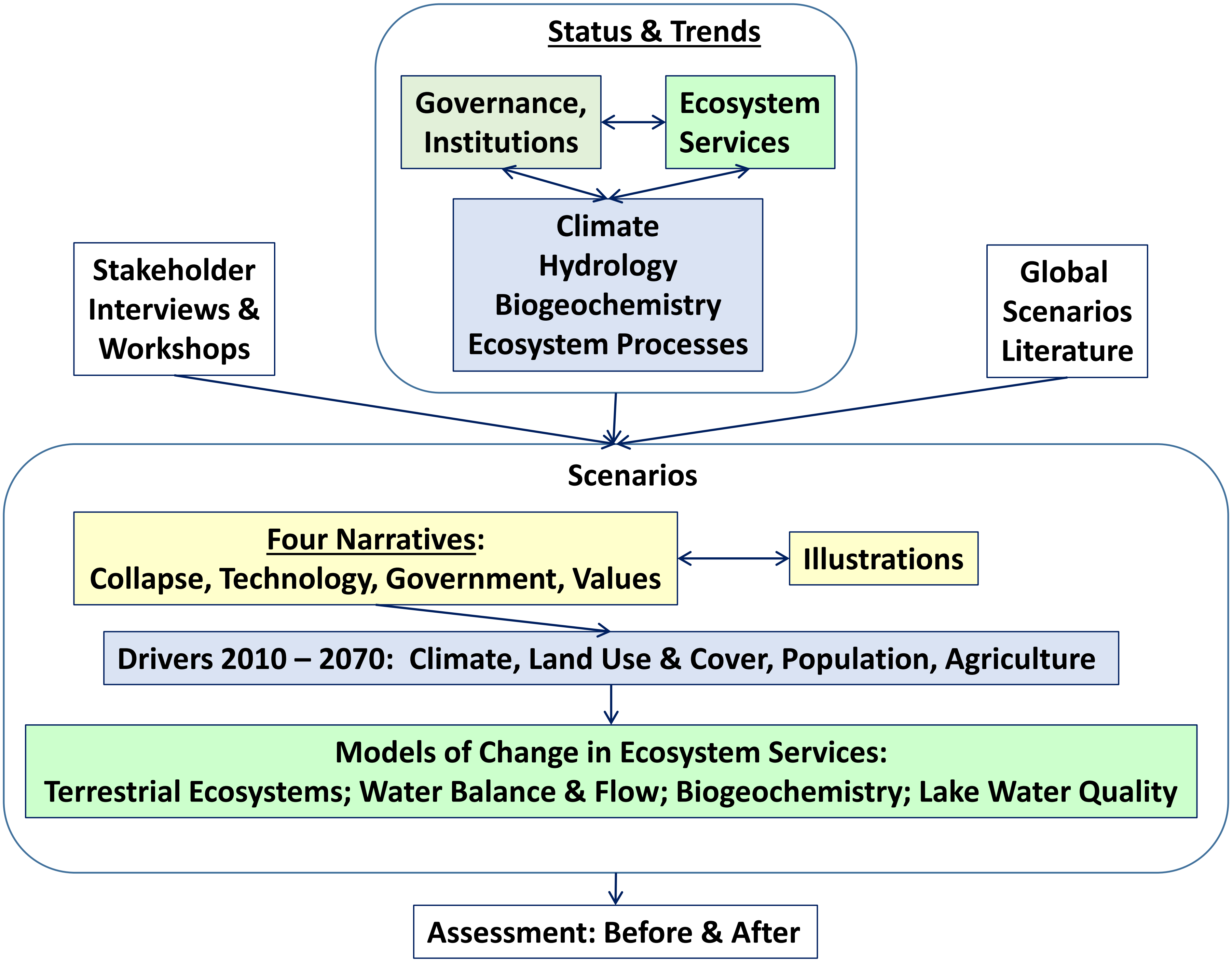
Assessing the Future of the Yahara Watershed (Madison Wisconsin)

Urbanizing agricultural region
1389 km^2; 372,000 people; 5 lakes
Remarkable long-term database
(see http://lter.limnology.wisc.edu)



Challenges to resilience:

- More variable precipitation, warming
- Phosphorus pollution of soils and waters
- Toxic algae blooms
- More frequent flooding
- Rising demand for land and water resources



Status & Trends
Governance, Institutions
Ecosystem Services
Climate
Hydrology
Biogeochemistry
Ecosystem Processes
Stakeholder Interviews & Workshops
Global Scenarios Literature
Scenarios
Four Narratives:
Collapse, Technology, Government, Values
Illustrations
Drivers 2010 – 2070: Climate, Land Use & Cover, Population, Agriculture
Models of Change in Ecosystem Services:
Terrestrial Ecosystems; Water Balance & Flow; Biogeochemistry; Lake Water Quality
Assessment: Before & After

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Routine expansion vs turbulent change is a key distinction

Both occur at the same time, at different scales

The backloop is poorly understood and highly influential

Models, games, and scenarios accelerate thinking about backloops and long-term change

Engagement of researchers with people in the SES is essential

The RAYS' Seven Principles provide a framework for organizing social-ecological research that engages with stakeholders