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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Summary
Resilience Network 1995-2000

Beijer Institute of Ecological Economics

Frances Westley

Carl Folke

Buzz Holling

Lance Gunderson

Brian Walker

Resilience Alliance 2000 – present

Stockholm Resilience Centre 2008 – present
Turbulent Change

Reorganization $\alpha$

Backloop

Release $\Omega$

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Adaptive Cycle

Reorganization \( \alpha \)

Growth \( r \)

Foreloop

Backloop

Conservation \( K \)

Release \( \Omega \)

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Example: Forest Fire

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

r: young trees, open canopy, low fuel

α: seed input, resprouts, etc.

Ω: Fire

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2-Level Panarchy, as a Stommel Diagram

Key Variable 1

Key Variable 2

Key Variable A

Key Variable B

Turnover Time

Spatial Extent

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


Phosphorus Inputs

Clear Water

Variable drivers

Phosphorus Builds up In Sediments

Turbid Water

Turbid Lake

Phosphorus recycling and inputs maintain high algae concentration

Clear Lake

Carpenter 2003 Regime Shifts in Lake Ecosystems
International Ecology Institute
General pattern:

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

Mistakes will be made.

Backloops will happen.


"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.

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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

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Carpenter, 2002, Ecology 83: 2069-2083
Two Big Attempts to Integrate Science and Stakeholders for Ecosystem Management

Case Studies in Applied Resilience
2006
Walker & Salt

Millennium Ecosystem Assessment Scenarios
2005
Carpenter and 96 others
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New Synthesis by Resilience Alliance Young Scholars (RAYS) group

Principles for Building Resilience
Sustaining Ecosystem Services in Social–Ecological Systems

Edited by Reinette Biggs, Maja Schlüter and Michael L. Schoon

Cambridge Univ. Press, 2015

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.

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.
Encourage 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 $\rightarrow$ 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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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 km²; 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