The Adaptive Cycle / Panarchy
Unsuccessful natural resource policies / management programs fail because do not understand:

- Ecological systems are complex, do not deal with uncertainties
- Problems in economic-ecological systems time-dependent
- Role of feedbacks
- Transformations in interacting human/natural systems
- Cross-scale problems
Problems occur when policies/management programs lead to loss of system resilience.

Development of Resilience Theory -

Attempt to understand nature of changes and interactions between human and natural systems.

Epistemological Approach
Patterns of change explained by several heuristic (= teaching, learning) devices:

- Adaptive cycle
- Panarchy
- Resilience
- Adaptability
- Transformability
Four phases:
r = early successional system
k = late successional system
Ω = system during a large, intense disturbance
α = system after disturbance but before becomes stable
Adaptive Cycle

• Heuristic model to understand change in complex systems

• Used to identify:
  - structure
  - patterns
  - causality

in the complex adaptive system studied

Gunderson and Holling, 2002
Adaptive Cycle

In ecosystem management cases – appear to be 3 properties that influence future responses of ecosystems, agencies and people:

1. Amount of potential for change – determines range of possible future options

2. Degree of connectedness between variables and processes:
   - how sensitive to external factors
   - how much does system control own destiny

3. Resilience – how vulnerable is system to disturbances
Four Phases of Adaptive Cycle

**r** – exploitation:
- rapid colonization
- rapid growth
- high dispersal ability
- entreprenurial market

**k** – conservation:
- slow accumulation
- slower growth
- higher competitive ability
- bureaucratic

r to k phases called the fore loop

Represents succession in ecosystems; development mode in organizations
Four Phases of Adaptive Cycle

α – reorganization:
- reduced resource loss
- more available for use
- pioneer species colonize
- ecosystem reorganizes
- innovation / restructuring in industry

Ω – creative destruction / release:
- have over connected system
- sudden release of material due to disturbance
- released material becomes available
- increased loss of resources

Ω to α phases called the back loop
Potential and Connectedness Dimensions

Start of cycle – $r \rightarrow k$:
- increased resource accumulation / sequestration
- increased connectivity and stability
- decreasing diversity (dominated by highly competitive species)

As near $k$ end, resources tightly bound – not available but represent increased potential
Disturbance - rapid release of resources
- lose tight, connected organization
- large loss of resources (loss of potential)

$\Omega \rightarrow \alpha$ - period of rapid reorganization – can have new combinations (alternate systems) – increased potential but low connectivity

$\alpha \rightarrow r$ - lower potential – loss of resources / pioneer species colonize and sequester resources
- who gets there first (initial conditions) determines how system develops
Third Dimension - Resilience

Increases and decreases - is dynamic factor - context-dependent

r phase:
- high resilience
- species with high adaptability

r → k: potential and connectedness increase but resilience decreases
- system more stable, efficient and predictable
- but more specialized entities more vulnerable to disturbance
\[ \alpha \text{ phase: have low connectivity, high potential and higher resilience} \]
- low connectivity allows for experimentation of different structures – has low cost to system
- have potential remaining from past cycle – legacy
- legacy + new entrants (pioneer species) can form new structures – alternative state

\[ k \rightarrow \Omega: \]
- rigid systems collapse
- strong destabilizing positive feedback
- as resources released, more structure destroyed….
- end with low potential and low resilience
Cycle has 2 objectives:

1. maximize growth and stability \((r, k)\)
2. maximize change and variety \((\Omega, \alpha)\)

Objectives cannot be maximized at same time – occur sequentially
- success of one leads to the other
The level of each of the three variables that characterize the four phases of the adaptive cycle

<table>
<thead>
<tr>
<th>Phase</th>
<th>Potential</th>
<th>Connectedness</th>
<th>Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>α Reorganization</td>
<td>high</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>K Conservation</td>
<td>high</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>r Exploitation</td>
<td>low</td>
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Are 8 possible combinations of 3 properties – only 4 shown
Two other, implied combinations:

- Poverty Trap
- Rigidity Trap

**Poverty Trap:**
- all 3 properties have low values
- have impoverished system

**Numerous examples:**
- systems commonly in state of crisis
- disintegration of societies

**Examples:**
- overfishing of Peruvian anchovies
- increased irrigation in semi-arid / arid habitats (Sumer)
Rigidity Trap:

- people and their institutions highly connected, rigid and inflexible

- common in bureaucratic systems

- high connectedness and resiliency; low potential

Example: resource management for commodities aim to reduce natural variation for economic reasons

Hindu caste system
Panarchy

• **Definition**: a hierarchical structure in which natural and human systems interact in never ending cycles of growth, accumulation, restructuring and renewal

• Cycles occur as nested sets across scales

• Combines *hierarchy theory* with concept of adaptive cycles
Panarchy – mix of hierarchy and adaptive cycle

Have adaptive cycles at each level of a hierarchy

Transforms hierarchies to dynamic, adaptive entities
Levels sensitive to disturbances during $\alpha$ and $\Omega$ phases

Lower level cycle enters $\Omega$ phase:
- collapse may cascade up to next level – causes crisis
- more likely if higher level in $k$ phase (low resilience)
- lower level collapse is disturbance on upper level

EXAMPLES: forest fires / spruce bud worm outbreaks

Events in upper levels affect smaller, faster levels
- lower level in $\alpha$ phase
- renewal opportunity greatly organized by $k$ phase of upper level

EXAMPLE: re-vegetation following fire
Adaptive cycle:

Developed from observations of ecological systems - many show the properties of the 4 phases

But what of human systems?

Some human institutions / societies show same sequences

BUT – 3 human factors may lead to increased potential of panarchy:
- foresight
- communication
- technology
Two alternate states:

1. Clear water phase
2. Turbid phase

Management aim – maintain resilience of clear water phase but decrease resilience of turbid phase
• Found P most important nutrient in lake eutrophication:

P added as fertilizer to farm fields

Excess P accumulates in soil and / or leaks to streams and lakes

Soil P – important variable – because is slow changing variable
Management History

1. Area settled – 1840
   Agriculture disrupts soil
   1940s – intensive agriculture
   Increased nutrient additions – collapse of water quality

2. New sewage system – stop sewage flowing into lake
   Little change – sewage P replaced by increased fertilizer use
   Increased farm P runoff – increased soil P around lake
   Invasion of non-native fish and plants – lower water quality
3. Plan to stop farm P runoff
Farmers uncooperative - no financial incentive

4. Biomanipulation of lake food web
Add piscivorous fish – eat invasive planktivorous fish
Worked until increased fishing pressure decreased piscivorous fish
Heavy rains – high erosion – large inputs of P from surrounding lands
What Use the Adaptive Cycle?

• Useful as heuristic tool
  - Teach non-experts how nature works
  - Show how different policies / actions may affect natural systems

• Good for describing past changes

• BUT – how useful for making predictions (is it like economics?)