Socio-Ecological Systems as Complex Systems

Slides prepared by Ana Elena Escalante

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System

Group of elements that are somehow related

- COMPOSITION: elements
- STRUCTURE: links among elements
- ORGANIZATION: composition + structure
- IDENTITY: organization + behavior (dynamics)

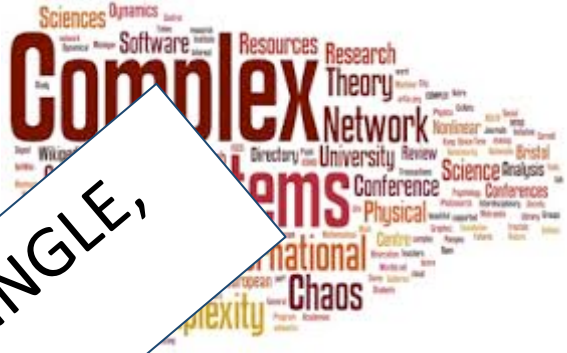
Solar system

Composition → planets, stars, satellites
Structure → relative position, mass
Organization → position with respect to the sun
Identity → dynamics: duration of traslation (year) and rotation (day)

Complex Systems

- COMPONENTS
  - Elements or agents (relative to the full system)
- PROPERTIES
  - Nonlinear interactions among components→ ***the whole is more than the sum of its parts***.
  - No central control (self-organization)
  - Emergent behavior → Results from the collective action of the individual elements.
    - Hierarchical organization
    - Processing (transmission of information)
    - Dynamics and feedbacks
    - *Evolution and learning*

Complex Systems



- COMPONENTS
  - Elements or agents "simples" (r e full system)
- PROPERTIES
  - Nonlinear interactio omponents→ ***the whole is more tho of its parts***.
  - No central co rganization)
  - Emergent h Results from the collective action o dual elements.
    - Hi ganization
    - (transmission of information)
    - cs and feedbacks
    - *ution and learning*

IT IS NOT POSSIBLE TO DEFINE THEM IN A SINGLE, SIMPLE EQUATION

Complex Systems
EXAMPLES

- Ant colonies, human brain, www, human genome, bird flocks.
    - Simple elements (ants, neurons, IPs, genes, birds) with respect to the behavior or collective functioning of the system (colony, brain, flocks, human body).

Complex Systems

- Mathematical Sciences-

- Hard to understand
- Mathematical tools and disciplines aim understanding through modelling-simplification
- Mathematical expression of complex systems provides a common platform-language

Complex Systems

- Dynamic systems-

- Are dynamic systems:
  - Solar system
  - Stock market
  - Global demography
  - Global climate

Complex Systems

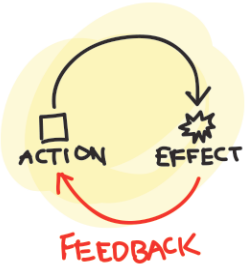
- Some disciplines that study them-

- EVOLUTION – The study of how the systems adapt to constantly changing environmental conditions.
- INFORMATION SCIENCES- The study of the representation, symbolisms and communication.
- COMPUTATION SCIENCES- The study of how systems process information and react to results.
- DYNAMICS- The study of how systems change in time. Describes how systems can change, make predictions. Allows for common language and mathematical tools to describe complex systems dynamics.

Socio Ecological Systems **(SES)**

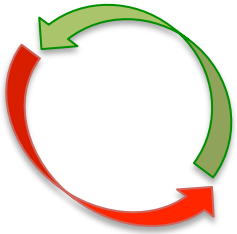
SES


generalized computational
transdisciplinary
comparison
relationships
scales collaboration
pain governance
real-world ostrom between
systems
discipline's
society
human
having
landscapes
information
complex
hard
environmental
problems cross-site
interactions
natural processes
perspectives
conservation
methods resource
existing
knowledge
resilience
data
human-natural
case
outside
inferences
energy
policy
spatial academia another
disciplines
relations
combining
making
insights models
cool
coupled
solve
environment
built design
reconciliation
scale earth
science
space
social
actionable
dynamic
differences bringing
socio-environmental
adaptation
merging
infrastructure
bridging
integration
new
ecosystem-services
considerations
answers nature intersection
language
creative
interdisciplinary
attributes
global
data-intensive
ideas
complexity
ecological
different similarities
qualitative
difficult
aggregation nature-society
management
feedbacks
applications overarching
quantitative
combinations functions
Word
It Out



Feedbacks

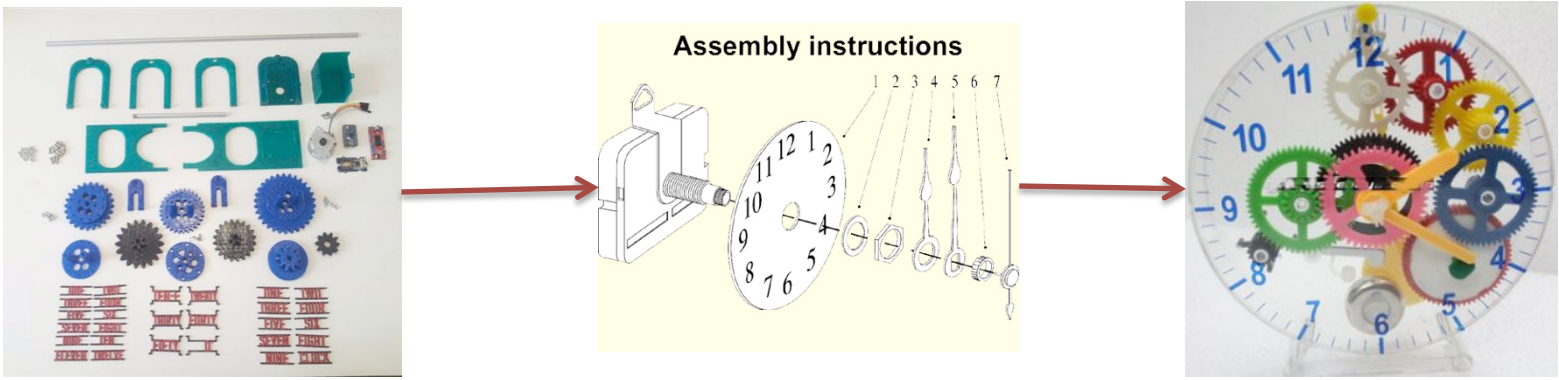
- Interdependency of ecosystems and social systems, or human-institutional agency



- Reciprocal relationships → human actions affect ecosystems and the resulting state of ecosystems affects actions.

SES
as complex systems

- For a while, the way of studying complex systems was through simplification (analytical reductionism) by describing the parts with great detail, as in a machine.



SES
as complex systems

Notes:
- Nonlinearity
- Self-organization
- Dynamic
- Feedbacks
- Adaptation
- **Externalities**

- Society represents one of the main forces of change in the biosphere and in ecosystems.
- Is key to understand the forces or drivers that motivate human actions.
- This drivers could be, and they rarely occur in isolation:
  - Economical
  - Political
  - Socio/cultural

Distance effects
Unertainty
“Wicked problems”
Decision making

SES
as complex systems

- Direct forces→ with a discernible and immediate effect of the action in the ecosystem (e.g. fire, mining).
- Indirect forces→ the effect of the action, does not show a discernible effect in the ecosystem.
  - Legislation: practices to reduce contaminants in England (1800)→ elevate chimmeneys, pollution went to Scandinavia.

SES – key attributes

- Nonlinearity: “the whole is more than the sum of the parts”.
- Nested Hierarchy: the effect at one specific level involves a balance of internal and external (other hierarchies) controls.
- Internal causality: no central control (self-organization).
- Dynamic stability: no equilibrium states.
- Multiple steady states: no single “ideal” state, given initial conditions, there are multiple possible states (attractors).
- Chaotic behavior: limited ability to predict the future.

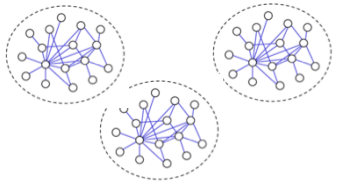
SES – properties

- ***Changing*** – episodic - Dynamics
- Spatially organized – not uniform, nor invariant, properties vary with the spatial scale - Hierachical, self-organization
- ***Multi-stables*** – No equilibrium point, many possible given a initial set of conditions.
- ***Afected by human agency trough policy and management practices*** – Fixed rules, independent of scale, they can lead to loose resilience and adaptability.

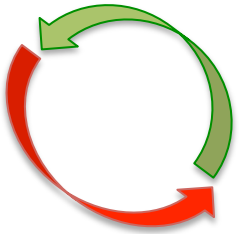
SES
"Vulnerability" as emergent attribute of the coupling

- "… vulnerability resides in the condition and operation of the coupled human–environment system, including the response capacities and system feedbacks to the hazards encountered". (Turner et al. 2003. PNAS)

SES – coupling



Biophysical system (ecological)

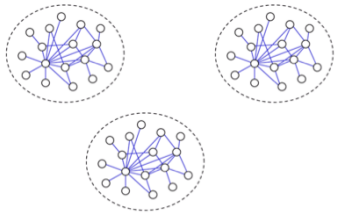


Coupling

THE CHALLENGE

SES scenarios (spatially explicit)

Socio-institucional system

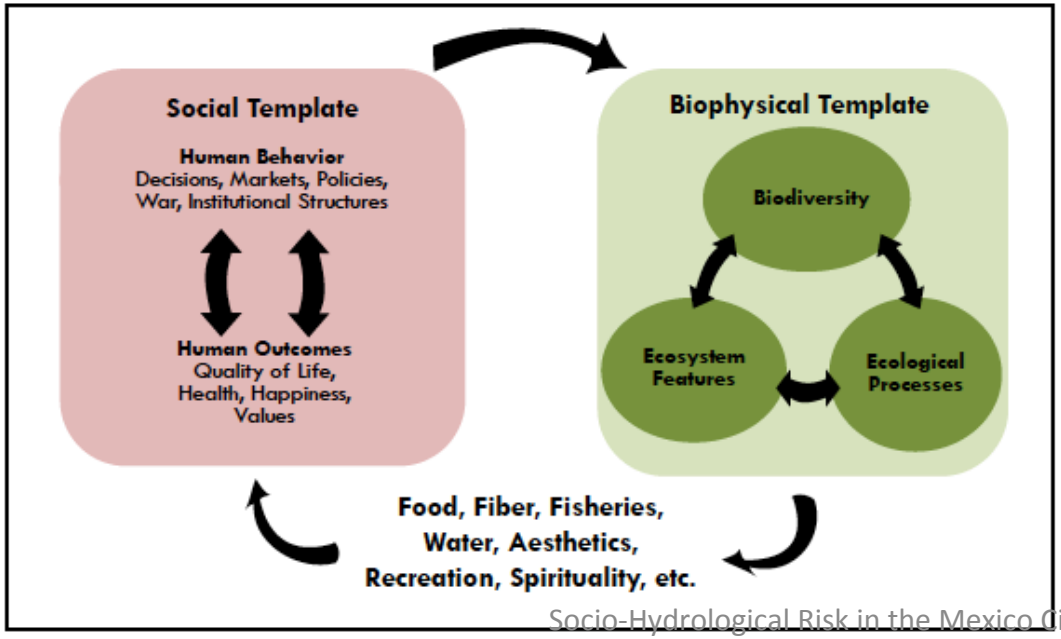


SES – coupling

- If vulnerability or future wellbeing depends on the interaction between the social and biophysical system, we need to find ways to study them coupled.
- Their study, emphasizes inter and transdisciplinary research, through natural sciences, social sciences and expert knowledge outside academia.

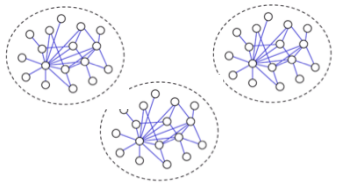
SES – coupling - Challenges

- Different types of data, approaches, theoretical frameworks and research strategies (e.g. natural sciences, social sciences).

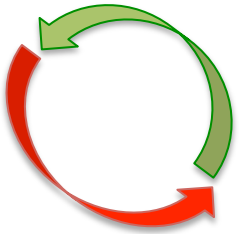


Socio-ecological synthesis

SES – coupling
Synthesis – Decision Making



Biophysical system (ecological)

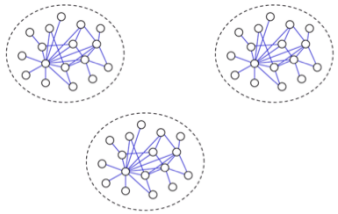


Coupling

THE CHALLENGE

SES scenarions
(spatially explicit)

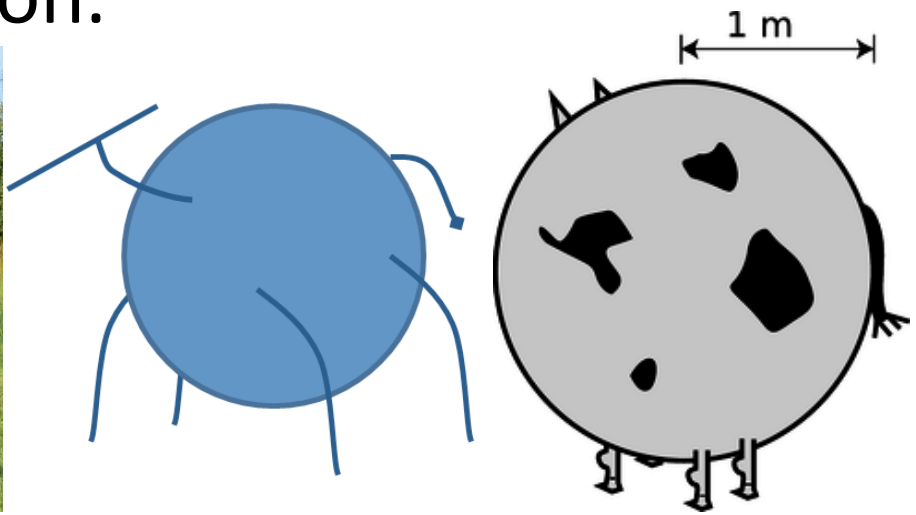
Socio-institutional system



Decision making / management

Complex Systems
- models -

- Simplified representation of a system, it aims to contain essential components and interactions, it aids systems study and communication.

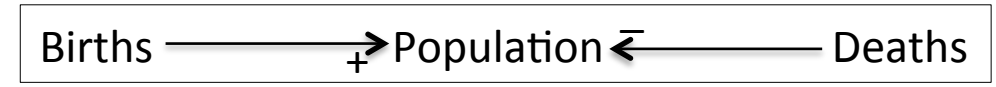


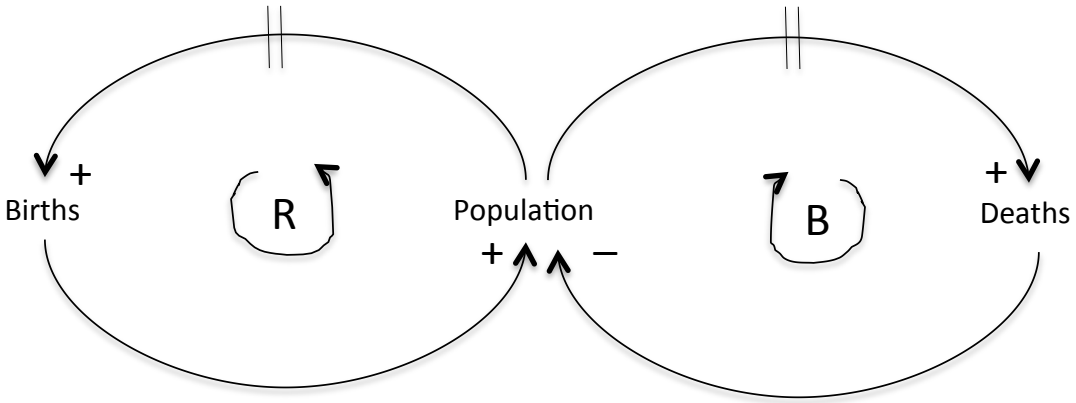
$$\epsilon_V = \frac{M_{\rm pl}^2 V_\phi^2}{2V^2}\,,$$

$$\eta_V = \frac{M_{\rm pl}^2 V_{\phi\phi}}{V}\,.$$

Complex systems
- models -

Note:
-feedbacks-





Complex Systems
- "**Useful Models**" -

- Models are tools that contribute to our understanding of a system or process and help to decision making.
- To be able to transform entities, ideas, concepts, into visual models that are easy to understand and to make experiments with, allow better communication of the problem and decision making.

Models

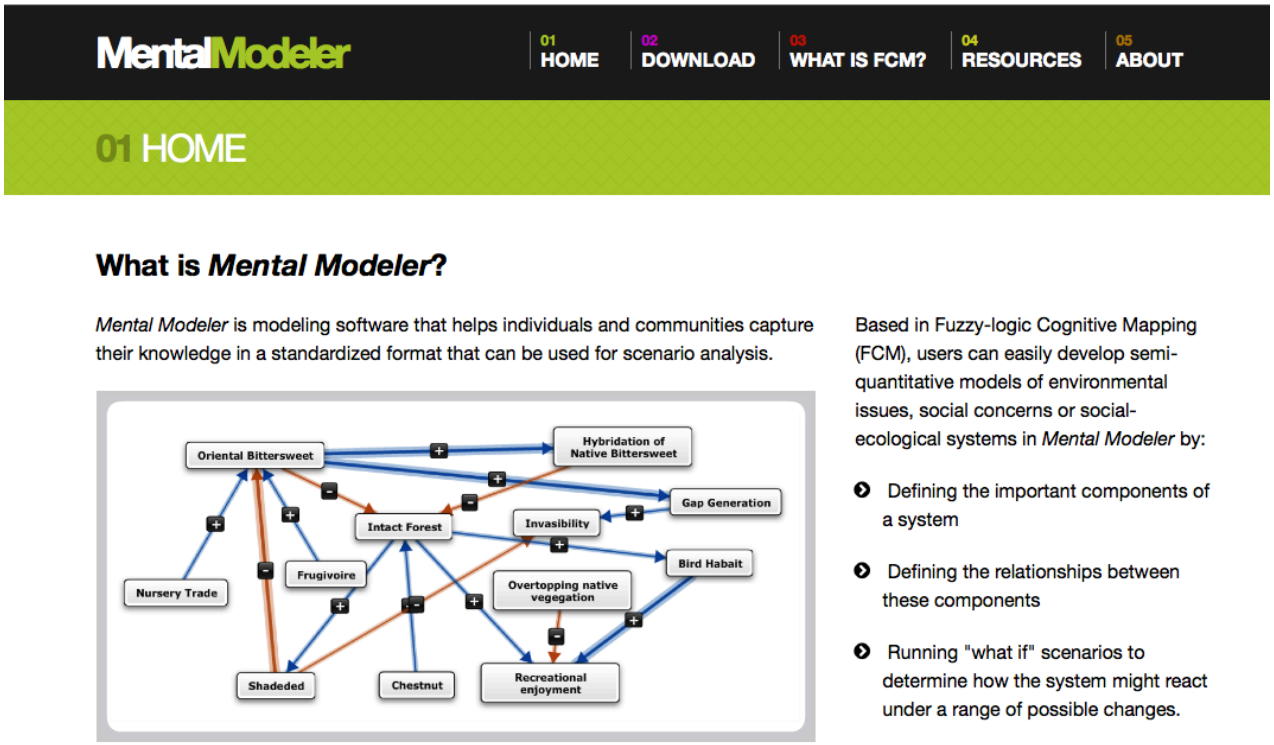
- Diagrams, System mapping-

- What is a model?
  - Simplified version
  - Captures de “essence”
  - Mathematical expression
  - Visual expression (diagram, map)
- Model map or diagram
  - Two components: variables and interactions
  - Variables: “things”
  - Interactions: relations among things (positive or negative)
  - Useful to investigate behavior of the system that were previously unseen (experimentation).

Models

- Diagrams, System mapping-

- Tools for mapping:
  - Mental modeler: www.mentalmodeler.org



Models

- Diagrams, System mapping-

- A simple example (using mental modeler)

Further reading

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