Complexity of Coupled Human and Natural Systems

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Outline

• Background

• Complexity of Coupled Human and Natural Systems: Concepts and Examples

• Telecoupling Framework and Applications

• Implications for Ecosystem Services and Poverty Alleviation
Coupled Human and Natural Systems (CHANS)

Integrated systems in which humans and natural components interact

Liu et al. 2007, Science
Types of CHANS (Examples)

- Social-Ecological Systems
- Socioeconomic-Ecological Systems
- Ecological-Economic Systems
- Human-Environmental Systems
- Population-Environmental Systems
- Social-Economic-Natural Complex Systems
Complexity

Attributes that are counter-intuitive and difficult to understand
Complexity of Wolong Nature Reserve
Wolong Nature Reserve

- “Flagship” reserve
- Established in 1975
- One of the largest (200,000 ha)
- 10% of wild pandas (~150)
- Local residents (> 4,500)
Feedbacks and Reciprocal Interactions
Contextual Factors (Geographical, Geological, Socioeconomic, …)

Policies
- Grain-to-Green Program
- Conservation Program
- Eco-hydroelectric Plant Program

People
- Demography
- Activities

Panda Habitat
- Distribution
- Quantity
- Quality

Socioeconomics
Surprises

Things that occur unexpectedly
Degradation of Panda Habitat Before and After the Reserve’s Establishment

(Liu et al., 2001, Science)
Why?

Reasons behind the Surprising Habitat Degradation
Population Size and Household Dynamics in Wolong

- Population Size
- Number of Households


Population Size:
- 1975: 0
- 1980: 0
- 1985: 200
- 1990: 400
- 1995: 600
- 1999: 800

Number of Households:
- 1975: 0
- 1980: 0
- 1985: 200
- 1990: 400
- 1995: 600
- 1999: 800
Fuelwood Consumption
Natural Forest Conservation Program (NFCP)

- Started in 2001
- To prevent illegal harvesting
- Households assigned to monitor forest parcels
- ~900 yuan subsidy, 20% of the annual household income in 2001
Dynamics of Household Numbers

Number of Households

Year

1989 1991 1993 1995 1997 1999 2001 2003 2005
Heterogeneity

Human-nature couplings vary across space, time, and organizational units
Forest Distribution in 1997

Changes in Forest and Panda Habitat in an Example Area

Liu et al. (2001) Science
Nonlinearity

Nonlinear relationships
Effect of Group Size on Forest Monitoring Effort

Yang et al. (2013) PNAS
Threshold (Tipping Point)

Transition point between alternate states
Average Fuelwood Consumption Per Capita in Wolong, China (1999)

Average Fuelwood Consumption (m$^3$/year/person)

Number of Persons in a Household
Legacy Effects

Impacts of prior human-nature couplings on later conditions
Percent of Plots with Panda Feces in Different Ages of Forests After Harvesting

Photos from Bearer and Data from Bearer et al. (2008) Biological Conservation
Time Lag

The amount of time before the effects of a change emerge
Time Lag in Response to Change in Fertility

An and Liu 2010 Population and Environment
Resilience

The capability to retain similar structure and functioning after disturbances
Earthquak Impact on Panda Habitat

Map by Andres Vina et al.
Comparisons of Complexity in Different Coupled Human and Natural Systems

- Reciprocal Effects
- Feedback Loops
- Nonlinearity
- Thresholds
- Surprises
- Legacy Effects
- Time Lags
- Resilience
- Heterogeneity

Liu et al 2007 Science
Distant Interactions
Migration Routes of 13 Bird Species

Bird migration routes. 1-Northern Wheatear, 2-Bluethroat, 3-Eastern Yellow Wagtail, 4-Dunlin, 5-Wandering Tattler, 6-Bartailed Godwit, 7-Arctic Tern, 8-Sandhill Crane, 9-Brant, 10-Smith's Longspur, 11-American Golden Plover, 12-Tundra Swan, 13-Semipalmated Sandpiper.

Seed Dispersal by Flying (2009)

Food Import to China (2010)

Food import to China (2010)
Percent (%)

- 0
- 0 - 1
- 1 - 5
- > 5
- No data

Liu 2014
Dynamics of Forest Products Import to and Export from China

Liu 2014
Telecoupling Framework
Definitions of Teleconnection, Globalization, and Telecoupling

**Teleconnection**
- Environmental interactions between natural systems over distances

**Globalization**
- Socioeconomic interactions between human systems over distances

**Telecoupling**
- Socioeconomic and environmental interactions between coupled human and natural systems over distances

Liu et al. 2013  Ecology and Society
Telecoupling of Coupled Human and Natural Systems

CHANS interact over distances
Major Components of the Telecoupling Framework

Sending System

Causes

Agents

Effects

Flows

Receiving System

Causes

Agents

Effects

Flows

Spillover System

Causes

Agents

Effects

Flows
Telecoupling Processes (examples)

- Migration (e.g., animals, people)
- Tourism
- Trade of goods and products
- Seed dispersal
- Species dispersal
- Species invasion
- Disease spread
- Atmospheric circulation
- Waste (pollutant) transfer
- Water transfer
- Knowledge transfer
- Technology transfer
- Investment
- Payment for ecosystem services
2013 Best Paper Award Winner:

Framing sustainability in a telecoupled world.

Two Examples
Example #1

International and National Telecoupling:

Telecoupling between Wolong Nature Reserve and the World
Examples of Telecoupling between Wolong and the World
Examples of Telecoupling between Wolong and the World

- Wolong Nature Reserve
- Pandas
- Tourists
- The World
Examples of Telecoupling between Wolong and the World

Wolong Nature Reserve

Migrants
Pandas
Tourists
Money

The World
Examples of Telecoupling between Wolong and the World

- Agricultural Products
- Information
- Pandas
- Tourists
- Money
- Fertilizers & Pesticides

Wolong Nature Reserve

The World
Number of Pandas Living outside Wolong

- By 1998: less than 20
- By 2004: 22
- By 2010: 85
Spatial Distribution of Giant Pandas Loaned to Zoos Outside Wolong in 2010
Tourists to Wolong
Number of Tourists to Wolong

Number of Tourists (Thousand) vs. Year


Number of Tourists (Thousand): 0, 50, 100, 150, 200, 250
Distribution of Sampled Tourists to Wolong (2006-2007)
Example #2

Regional Telecoupling:

Payment for Ecosystem Services
(Clean Water)
Dynamics of Water Use by Sector in Beijing

Liu and Yang, 2013, PNAS
Payment for Paddy Land-to-Dry Land (PLDL)

Zheng et al. 2013 PNAS
## Research Gaps on Payments for Ecosystem Services Programs in the Context of Telecoupling Framework

<table>
<thead>
<tr>
<th>Components of the telecoupling framework (2)</th>
<th>Definitions of the telecoupling components with regard to PES</th>
<th>Specific telecoupling components studied or not studied by Zheng et al. (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sending systems</td>
<td>Systems that provide ecosystem services</td>
<td>Upstream of Miyun Reservoir watershed in Hebei Province</td>
</tr>
<tr>
<td>Receiving systems</td>
<td>Systems that receive ecosystem services</td>
<td>City of Beijing</td>
</tr>
<tr>
<td>Spillover systems</td>
<td>Systems that affect or are affected by interactions between sending and receiving systems</td>
<td>Other areas affected by the PLDL (e.g., surrounding areas in Hebei and other areas that send water to Beijing)</td>
</tr>
<tr>
<td>Flows</td>
<td>Movement of ecosystem services and associated materials, energy, information, such as cash payments</td>
<td>Movement of water and cash between Hebei and Beijing; movement of materials/energy/information between Beijing (or Hebei) and spillover systems</td>
</tr>
<tr>
<td>Agents</td>
<td>Service providers in sending systems; beneficiaries in receiving systems; involved organizations or people in sending, receiving, and spillover systems</td>
<td>Participant households in Hebei; local governments in Hebei and Beijing; agents in spillover systems</td>
</tr>
<tr>
<td>Causes</td>
<td>Environmental (e.g., availability of ecosystem services in sending systems); Socioeconomic (e.g., demand for ecosystem services in receiving systems); Political (e.g., agreements between sending and receiving systems); technological (e.g., channels to transfer ecosystem services)</td>
<td>Decline in water quantity and quality in Beijing and Hebei; population growth and household proliferation in Beijing; rapid economic growth; increasing water demand in Beijing; conflicts and shared political interests between Hebei and Beijing; feasible technologies of transferring water; systems that affect hydrological dynamics in Beijing and Hebei</td>
</tr>
<tr>
<td>Effects</td>
<td>Socioeconomic and environmental effects in sending, receiving, and spillover systems; feedbacks</td>
<td>Increase in water yield and decrease in nutrient pollution in Miyun Reservoir Watershed; opportunity costs of conserving water to service providers; transaction costs; economic costs to Beijing residents; changes in livelihood of service providers; changes in livelihood of beneficiaries; environmental effects (e.g., on groundwater level, land cover) in Beijing; feedbacks such as changes in payments according to changes in water quantity and quality; socioeconomic and environmental effects on spillover systems</td>
</tr>
</tbody>
</table>

Underlined items refer to issues that are not studied by Zheng et al. (1).
Key Topics for Telecoupling Research

• Consider sending, receiving and spillover systems together as a telecoupled and networked system
• Understand socioeconomic and environmental feedbacks among systems
• Evaluate causes, agents, flows of telecoupling processes
• Analyze impacts of telecouplings on system structure, function, pattern, dynamics, and sustainability
Rewards of Complexity Research

- Appreciate complex reality
- Anticipate and prepare for surprises
- Identify research gaps
- Develop more effective policies
- Generate media interest in research results
The Coupling of People and Nature

Traditionally, ecologists have viewed humans in an ecosystem as something of a nuisance — contaminating samples, skewing data and clouding scientific analyses. “But the human aspect of an ecosystem is crucial,” said Jianguo Liu, who leads the International Network of Research on Coupled Human and Natural Systems, or Chans-net, a network of 1,300 ecologists, economists, and sociologists.

“The central message of Chans is that humans and nature are coupled, just like husband and wife,” says Dr. Liu, director of the Center for Systems Integration and Sustainability at Michigan State University. “They interact, work together, and the impacts are not just one way. There are feedbacks.”
The New Science of Telecoupling Shows Just How Connected the World Is—For Better and For Worse

By Bryan Walsh @bryanjwalsh | Feb. 23, 2011 | Add a Comment

I've got one more tidbit from last weekend's meeting of the American Association for the Advancement of Science (AAAS), and it's nothing less than a new scientific concept: telecoupling.
Implications of Complexity Research for Ecosystem Services and Poverty Alleviation
Complexity (Hypothetical and Real) in Ecosystem Services and Poverty Alleviation

- Ecosystem services and poverty may form reciprocal interactions and feedbacks.
- Ecosystem services and poverty alleviation may have nonlinear relationships.
- There is time lag between poverty alleviation efforts and the end of poverty, and between ecosystem restoration effort and sustainable ecosystem services.
- Poverty alleviation and improvement of ecosystem services may not occur until a threshold or tipping point is reached.
- Many factors have legacy effects on poverty alleviation and ecosystem services.
Needs of Complexity Research on Ecosystem Services and Poverty Alleviation

• Long-term research to identify complexity (e.g., time lag, legacy effect, feedbacks)

• More integration of various disciplines (e.g., natural and social) to understand reasons behind complexity

• More coordination among different coupled systems across the telecoupled system
Summary

- Complexity is common in coupled human and natural systems
- Complexity research has many challenges and rewards
- Embrace complexity!
Acknowledgements

• NSF

• NASA

• Numerous collaborators
References

• Liu et al. 2007 Science
• Liu et al. 2013 Ecology and Society
• Liu and Yang 2013 PNAS
• Liu 2014 Asia and Pacific Policy Studies

• http://csis.msu.edu/telecoupling