Complex Systems of Valuation

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- Objective of paper:

  To prove that has human forces on the planet increase, ecosystem service valuation needs to switch from choosing among resources to valuing the avoidance of catastrophic ecosystem change

Characteristics of ecological and economic systems - Similarities:

- They are complex networks of component parts linked by dynamic processes
- They contain biotic and abiotic components
- They are open to exchanges across their boundaries

- Ecosystem boundaries are somewhat arbitrary and economic boundaries expand and contract

Characteristics of ecological and economic systems - Differences:

- Human perception shapes our species' behaviors, and this perception is expressed in economic and other social systems as values

- Humans place a value on ecosystem functions because they are essential for their existence
- Humans place a value on ecosystems for their cultural and emotional needs

- *Ecosystem Service* – termed used to make apparent that the structure and function of ecosystems provide value to humans (Daily, 1997)

Characteristics of Complex Systems
Structural features and boundaries

- Components – state variables and stocks
- Interactions – flows of matter, energy, or information
- Open systems such as ecological and economic systems have fluxes in and out of the system boundaries (imports and exports). Fluxes in and out of the system can be defined as sources and sinks

- Studying systems:

  1) Particular site such as environmental impact assessment

  2) Larger scale to determine the multiple impacts of disturbances on a system

Characteristics of Complex Systems
Dynamics

- Interactions of components, processes, and systems with other systems which give rise to complex behaviors
- The interactions can be relational, physical, or combination

- Complex, interactive systems tend to converge to stable states or dynamic equilibria, where the flows and processes are balanced.
- This is measured by resistance and resilience

- Resistance measures how unyielding a system is to a disturbance
- Resilience measures how quickly a disturbed system returns to its equilibrium or its ability to maintain or recover its structure and pattern of behavior in the presence of stress (Holling, 1986)

System Resilience

- Length of time it takes a system to recover from stress (Pimm, 1984)
- Magnitude of stress from which the system can recover, or the system's specific thresholds for absorbing various stresses (Holling, 1986)

- Example: overgrazing or climate change can push a vegetative system into a new stability domain – desertification. This can be reinforced by feedback loops that maintain high temperatures and low water and nutrients (O'Neill and Kahn, 2000)

- Therefore, included in the understanding of complex systems is the ability to inform decision makers about when and under what circumstances an undesirable substantive state will occur (refer to previous example), diminish or enhance the value of ecosystem services

Concepts of scale
Ecosystems and scale

- The scale of an ecological property is usually discussed in terms of the temporal or spatial scale at which the property has the highest level of coherence
- Ecosystems should be defined in terms of the scale of the question or problems posed

- One component of understanding ecosystems is to learn how tight or loosely coupled the processes are at different scales because this clearly defines the hierarchies of interacting systems

- Examples:

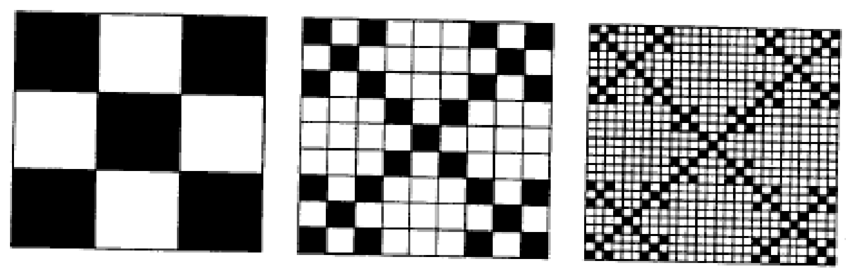
1) Events such as hurricanes and fire set physical constraints on a small scale and shorter period, there will be tighter coupling among components and processes with similar rates and overlapping spatial scales (O’Neill, 1989; Levin, 1992)

Fractal Dimension

- Physical, biological, and ecological properties scale as fractions. Fractals have been used to describe systems such as cloud shape, river drainages, and landscape patches because the size of units are all proportional according to the same proportion

Taken from, “Cellular automata and fractal urban form: a cellular modelling approach to the evolution of urban land-use patterns” by R. White and G. Engelen

The fractal dimension D (D<2), where D is the fractal dimension, shows that as the object expands in cell space the number of cells composing it grow less rapidly than the number of cells in the square necessary to contain it, so that the object becomes more sparse.



(a) (b) (c)

Figure 5. Three stages in the construction of a Sierpinski carpet: (a) $S = 1$, (b) $S = 2$, (c) $S = 3$, where S is the step number.

- Complex systems generally contain processes that function at different, but often overlapping, time and space scales.

Concepts of scale
Economic systems and scale

- Economic systems are composed of elements interacting through exchange, production, and consumption processes by which materials and energy are transformed and moved through the people and institutions to create income, wealth, and well-being

- As stated for ecosystems, the appropriate analytical scale for economic systems depends on the research question.

- Resilience or instability can be considered at different scales in economic systems
- Properties may emerge on a macro or micro scale. Example: haddock – the market may be non-resilient and under certain conditions harvesting will deplete the species; however, the macro market may not be impacted and remain stable.

- Understanding all the consequences of economic scale requires that the scale of analysis encompass impacts other than the direct cost of production
- The value of natural systems for providing stability to markets depends on the connection between directly and indirectly impacted markets.

- Example: In many instances natural selection stabilizes a fish population over time. The economic value of the service depends on whether the stability is important to economies. If there are other species available to harvest, then, fisherman have no problem moving between markets.

Valuation of ecological goods and services
Ecosystems and value

- Valuation begins with identifying the key structures, functions, and interactions of systems, and probing these to understand which are important in maintaining their condition, dynamics, and production of ecosystem services.

- Many ecologists find that the valuation of ecosystems is of little importance; they feel that the factors governing ecosystem dynamics are the critical determinants of the human-environment interactions.
- The biosphere is not in jeopardy it is the Homo sapians that are in jeopardy

Valuation of ecological goods and services
Separability of ecosystems and economic systems

- The economic system is usually viewed as a complex dynamic system that interacts with a separate environmental system through inputs and outputs.

- Under what set of conditions is the concept of a separable economic system legitimate?
- When looking at a linear model, systems can only be separated out when one system operates at a magnitude faster than the rest of the system.

First, why do they have us look at a linear model when ecosystem and economic models are non-linear systems in which meta-stable states, bifurcations, and the possibility of being bumped to a a different, less desirable equilibrium are not considered?

- The authors are referring to comparative statistics – looking at how the solution of a problem will change if the values of the model parameter change.
- Example, how will harvest rates change if interest rates change? The model assumes that small changes in the parameters don't lead to large changes in the optimal solution.
- According to the authors, in non-linear systems with more than one equilibrium state the assumptions under which comparative statistics and non-market valuation operate break down.

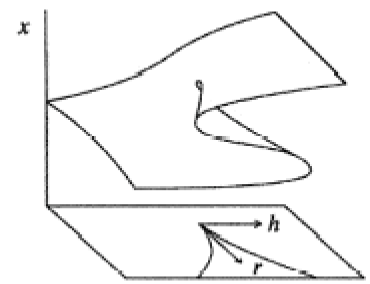
Explanation taken from Dawn Parker

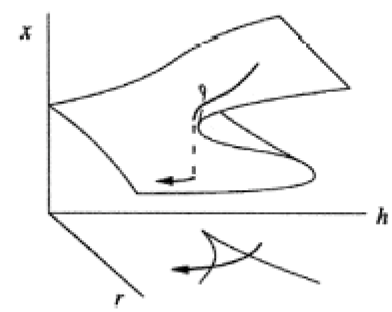
Example: Homo sapiens respond more rapidly than the entire ecosystem of which it is part. This difference in scale is required for stability; therefore, economics appears to play a small role in the system; however, the distinction becomes important as the scale of human activity such as forest harvesting increases.

- This example shows that the dynamics of the economic system are determined by the total environment (ecological and economic) system.
- At high levels economic activity, ecosystems will not remain stable and at low levels of economic activity, ecosystems are likely to remain stable.

- As the assimilative capacity is exceeded, the ecological system can enter into a "metastability"
- The ecological system reaches a level in which a minor disturbance can move the system to a new state.
- Examples: overgrazing and overfishing

- In these situations, the system moves into a region of parameter space where a ‘fold catastrophe’ exists
- Examples include: pest outbreaks, ice cap dynamics, and mass faunal extinctions
- A problem is the mathematical model demonstrates that catastrophe change can not be anticipated without complete knowledge of every component and a perfect model of the interactions





Question: If a system is already in a stable state, what would cause it to move to another stable state? How can it move from one stable state without falling into a state of non-stability?

Answer / Example: Take a twig moving along a rapid in a creek. It may hang out in a pool for quite awhile until a slight increase in water flow pushes it out of the pool and into another pool where it will again hang out. ** When the twig left its current state, a dynamic force or process pushes it to a new state. In contrast, there are dynamic systems where the system will move back to its current state when it is slightly pushed away from it.

Explanation taken from Dawn Parker

Valuation of ecological goods and services
Marginal and non-marginal services

- Valuation is the determination of the difference something makes.
- Economic valuation establishes the difference something makes to well-being in the context of goods and services available and establish whether the differences analyzed will be partial or general

Distinguishing between a continuum of ecological / economic conditions

- 'marginal revenue' – at one end of the continuum – a high degree of certainty and predictability in understanding the relation among system components; economic and ecological conditions is the same
- 'non-marginal revenue' – at the other end of the continuum – a set of conditions wherein the assumptions necessary for marginal economic valuation no longer hold

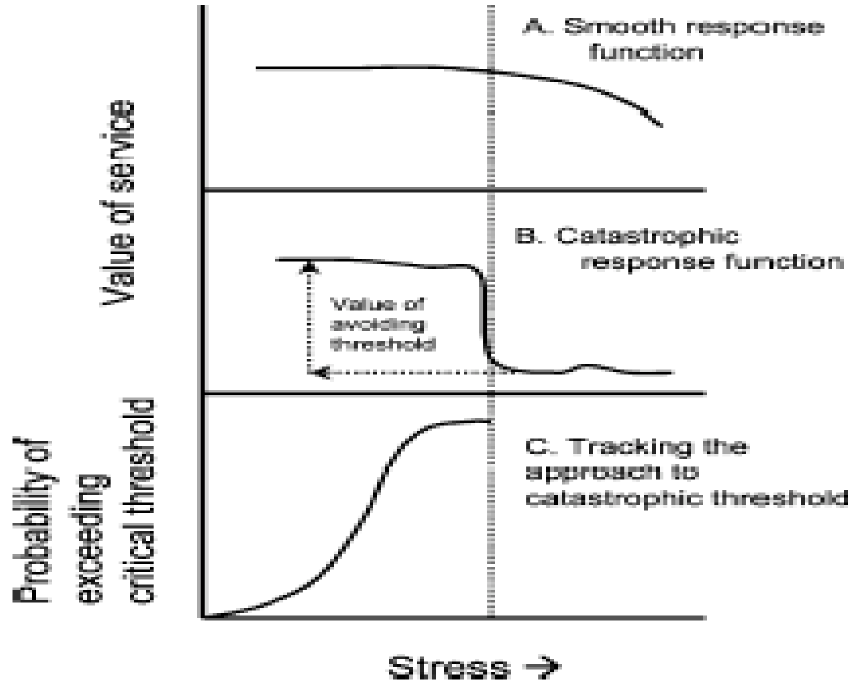


Fig. 2. Value responses to stress under 'marginal' (well-behaved dynamics) and 'non-marginal' (nonlinear, threshold dynamics) system behaviors.

Dotted line depicts the critical threshold; the top panel is the marginal regime; the middle panel is the non-marginal regime

The downward-sloping (almost vertical) part of the solid line represents the process of bifurcation, moving from one stable state to another. Figure B

- A. When the equilibrium remains far from bifurcation, marginal analysis will inform us when we are close to an undesirable change because the change will be continuous and negative
- B. How we conceive of the change in values when the system is in the vicinity of a bifurcation
- C. There will be a region wherein a small change in the ecosystem results in a large increase in the probability of dramatic system change in response to infinitesimal stress

- A marine fishery is an example of a system that can move from a marginal to non-marginal regime
- When a fish species has been harvested to the point of extinction, the fishermen may be able to harvest another type of fish and remain in a marginal regime; however the extinction of a fish species moves to a non-marginal regime

Conclusion

- When ecosystem are forced away from a stable equilibrium, the relevant value concepts shift from utility to risk-avoidance.

Have we reached this point for some ecosystems?

- When the natural world can be divided into forms of capital that provide critical services for which the capital may be substitutable or non-substitutable, two separate valuation systems are needed
- When preferences toward ecosystem services are vague, poorly formed, likely to change over time, and likely to change substantially with new information, ecological based values will be more useful as indicators of conditions and scarcities of a potentially valuable natural service

- No single valuation scheme will work well over all circumstances. Indicators need to be developed to determine which set of system conditions we are in or moving towards
- Need to develop and improve indicators that serve as warnings about and away from thresholds of dramatic declines in ecosystem services