SYSTEMS RESILIENCE AND ITS POLICY CONSEQUENCES: PROPOSAL FOR WORK AT IIASA

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The purpose of the project is to explore the behaviour of ecological and resource systems, to develop techniques of measuring these properties and to relate them to a planning framework.

Objectives

(i) review theoretical and empirical analyses appropriate for ecological, resource and anthropological systems; review methologies designed to analyse their dynamic behaviour;

(ii) using a set of ecological and regional models described below, develop ways to interpret information contained within them;

(iii) on this basis, define each of the behavioural attributes of the models - particularly that of stability and resilience - and give them numerical representation;

(iv) design a policy framework that emphasizes maintaining open options and the increase of systems resilience rather than more traditional equilibrium-centred approaches;

(v) develop methods to aggregate and disaggregate our understanding of complex dynamic systems in a form useful and usable for planners and policy people.

Background

We propose to use three models we have developed as the core for our project. They represent three different classes of ecological models - one with a small number of state variables and a large number of parameters per variable developed from very rich experimental data (predator/prey system); one with a larger number of state variables (27) and a small number of parameters per variable, developed by a combination of field data and experimentation (lake ecosystem); and one a regional model similar to the preceding but developed by inter-disciplinary groups of experts from the relevant fields. Although this model is less rich in data and well-tested relationships, it has a broader representation of economic, social and policy dimensions.

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In our explorations of the behaviour of these models a number of different characteristics have emerged. One of the more interesting concerns a general tendency of the modelled systems to exhibit more than one domain of "stability" or attraction around equilibrium points, trajectories or limit cycles, with at least one domain bounded by an unstable limit cycle. The feature of these boundaries is that they, rather than the area immediately surrounding the various equilibrium states, are critical to the overall behaviour of the system. Points on either side of the boundary will ultimately track to their respective predictable equilibrium states; points near the boundary are liable to be flipped across it from one domain of stability to another in the face of small perturbations. The size of the domain, and the strength of the damping forces near its bounding edge, thus in large part characterize the ability of the system to maintain a structural integrity in the face of unexpected perturbations. If the domain is relatively small then a small perturbation can flip the system into another domain, thus altering its subsequent behaviour out of all proportion to the size and duration of the perturbation applied. Moreover, the weaker the damping forces in the vicinity of the boundary, the greater the likelihood that a small perturbation will cause that boundary to be crossed, regardless of the size of the respective domains. Finally, we note that in our ecological examples the parameter values occurring in nature seem generally to produce domains that are large, with rather weak damping around the equilibrium and strong damping at the boundaries.

From an equilibrium-oriented viewpoint, then, these systems can appear rather weakly damped and quite sensitive to disturbance. But from the viewpoint of the boundary, they are immensely stable with a high degree of persistence. In a sense this is what ecologists have always been saying - that what is important is not the efficiency of such systems, but the probability of their persistence. This orientation switches attention away from events near the equilibria to the events near the boundary of stability, and it is this switch that for us is placing so much of our understanding in a very new light.

We see some interesting consequences that could emerge by applying the resilience concept to policy analysis and the planning process. The analyses described above lead to the realisation that natural systems have experienced traumas and shocks over the period of their existence and the ones that have survived have explicitly been those that have been able to absorb these changes. They have, therefore, an internal resilience related to both the size of their domain of stability and the nature of the damping forces near the boundaries of the domain. So long as the resilience is great, unexpected consequences of an intervention of man can be absorbed without profound effects. But with each such intervention it seems that the price often paid is a contraction in the domain of stability until an additional incremental change can flip the system into another state. In a development scheme this would generate certain kinds of "unexpected" consequences in response to deceptively 'minor' perturbations - a freeway that changes the morphology of a city so that the urban core erodes; an insecticide that destroys an ecosystem structure and produces new pest species. We seem now to be faced with problems that have emerged simply because we have used up so much of the resilience of social and ecological

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systems. Up to now the resilience of these systems has allowed us to operate on the presumption of knowledge with the consequences of our ignorance being absorbed by the resilience. Now that the resilience has contracted, traditional approaches to planning might well generate unexpected consequences that are more frequent, more profound and more global. The resilience concept provides a way to develop a planning framework that explicitly recognises the area of our ignorance rather than the area of our knowledge.

We are now, therefore, at a point where an intriguing concept has emerged, a set of models are available to explore the concept, and a policy framework is hazily emerging that emphasizes resilience and the maintaining of future open options. We are close to completing a significant study of Systems Resilience and its Policy Consequences, and plan to use the year with IIASA to bring it to fruition.

<u>Work Outline</u>

I <u>Theory of Systems Behaviour</u>

A) Review of Systems Behaviour

(i) ecological systems
(ii) economic systems
(iii) anthropological systems

B) Review of Technical Approaches to Analyzing Systems Behaviour

(i) general systems theory
(ii) control systems, frequency domains
(iii) state space

II <u>Systems Behaviour in the Real World</u> (analysis of examples from ecology, economics, and cultural anthropology)

A) Classification of Perturbations and Responses

(i) perturbation rates, durations
(ii) driving and state variables; parameters

B) Self-contained and reasonably homogeneous systems

C) Considerations of process analysis, temporal heterogeneity, and spatial heterogeneity.

D) Simulation study using models of ecological systems

(i) predator/prey (few state variables, many parameters)
(ii) ecosystem model (many state variables, few parameters/variables)
(iii) regional model

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III The Synthesis

A) Summary of systems behaviour

B) Aggregation and degree of resolution of state variables (the concept of functional "roles")

C) Stability and resilience

D) Behaviour "types"

IV Measurements of Resilience and Stability

A) Theoretical, using models

B) Empirical, - with field examples

C) The problem of handling many dimensions...

V Applications - Role of technical information in decision making

A) Defining roles in the planning process

B) Information needs and contribution of each role

C) Aggregation and disaggregation of information appropriate for each role:

(i) research
(ii) development of strategic, alternatives
(iii) evaluation of alternatives at tactical and value level (resiliency and stability indicators, etc.)

D) Techniques of presentation, using examples (e.g. James Bay Development Project) -- workshops, graphical display, management 'slide rules'