

DYNAMICAL SYSTEM STUDIES IN MODEL ECOSYSTEMS

by

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DEDICATED
TO MY (Late) MOTHER . . .



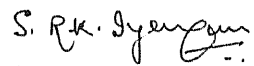
CERTIFICATE

This is to certify that the thesis entitled

“DYNAMICAL SYSTEM STUDIES IN MODEL ECOSYSTEMS”

which is being submitted by RANJIT KUMAR UPADHYAY for the award of the degree of DOCTOR OF PHILOSOPHY in MATHEMATICS to the INDIAN INSTITUTE OF TECHNOLOGY, NEW DELHI, is a bonafide record of research work done under my guidance and supervision.

The thesis has reached the standard fulfilling the requirements of the regulations relating to the degree. The results obtained in this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.


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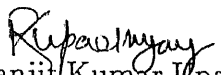
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(Ranjit Kumar Upadhyay)

ABSTRACT

This thesis, entitled “Dynamical System Studies in Model Ecosystems”, is a study of Chaos, Stability, Complexity and effect of perturbations in model ecosystems. The subject matter has been divided into seven chapters. We have studied the following aspects of the dynamical behaviour in model systems.

- (i) An attempt is made to understand why chaotic dynamics has received poor evidential support from field studies. The reasons for the failures of the attempts to observe chaos in natural populations are studied. A new technique (Pseudo-prey method) is used to study the dynamical behaviour of the 3D nonlinear systems.
- (ii) Four model systems which describe some of the common ecological situations in terrestrial ecology are studied to answer the question whether an ecosystem evolution is chaotic in certain situations.
- (iii) Using some model systems, we tried to answer the following question: Is complexity necessary for the stability of an ecosystem ? In this context, we also need to consider the following : (a) Does the structural complexity guarantee structural stability?
(b) What is the relationship between structural stability and dynamical complexity ?
- (iv) Some issues regarding the effects of genetic and ecological factors on the extinction of species in ecological systems are studied.
- (v) The influence of environmental perturbations (seasonal and sudden) on the evolutionary modes of the model ecosystems are studied.
- (vi) Eight 2D and 3D model systems and their perturbed versions are studied to determine (a) whether stable regions or part of the stable regions are converted into chaos due to seasonal perturbations, and (b) whether part of the chaotic regions are dragged (converted) into stable regions.

Numerical simulation studies using the bifurcation diagrams, calculation of basin boundaries, two dimensional parameter scans etc., are made and the following conclusions are drawn from these studies:

- (i) Crisis limited chaotic dynamics was found to be the primary cause for the existence

of chaos in very narrow ranges of the parametric values.

(ii) The study suggests that the possible cause for the failure of the attempts to observe chaos in natural populations, might not be the poor quality of data but may be an ecological reality.

(iii) It is found that chaos exists in narrow ranges of parameter values. It was concluded that the existence of chaos in narrow parameter ranges might have been caused by the crisis induced sudden death of the chaotic attractors.

(iv) The model systems with interference among individuals of predators do not support chaotic dynamics at all. Even stable limit cycle solutions are not observed. At best, some model systems admit chaotic solutions in very narrow parameter regimes as well as in regions of natural measure zero. We conclude that for the corresponding real systems, chaos may not be a suitable representation of the system dynamics.

(v) Basin boundary structures provide a qualitative idea of the dynamical complexity of a system. The results obtained for the model systems indicate that structural complexity is not essential for dynamical complexity to exist. For systems which possess smooth basin boundaries with one of the attractors existing in a narrow parameter range, it is difficult to discuss its stability. In certain cases, when riddled basins are found, even qualitative predictability is denied.

(vi) In the case of the species extinction problem the simulation experiments suggest that both the factors, genetic and ecological, are important and that they should be given suitable weightage in working out strategies for any conservation efforts. A general conclusion which emerges from this study is that the species belonging to the higher life form, especially, generalist predators are less prone to extinction in comparison to those which are placed in the interior of the food-chain. The sexually reproducing predators bring stability, diversity and thus prosperity to the terrestrial ecosystems.

(vii) Sudden perturbations are found to influence the dynamical modes significantly. The co-existence of two or more distinct attractors for the same set of parametric values

suggest that sudden environmental disturbances may alter the dynamical regimes of these systems. Two dimensional parameter scans suggest that even a smooth (seasonal) perturbation which bring changes in system parameters and thus decide different dynamics, are able to induce variations in these modes frequently. The analysis suggests that the influence of sudden and unforeseen perturbations on the ecosystem dynamics can be controlled provided the dynamical complexity is under control.

(viii) Seasonally induced perturbations of weaker strength are found to transform stable limit cycle attractors into chaotic ones in the case of the two-dimensional systems. Strong perturbations are required to effect the same in the case of the three dimensional ecosystems. In both the 2D and 3D systems, chaotic attractors were not destroyed by the influence of seasonality. These results may be helpful in working out strategies for the management of man made and natural ecosystems involving economically important species.

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