# Preface

The problems of understanding complex system behavior and the challenge of developing easy-to-use models are apparent in the fields of environmental management and economic development. We are faced with the problem of reconciling economic activities with the goal of preserving or increasing environmental quality and quality of life. In economic and environmental problems, many parameters need to be assessed. This requires tools that enhance the collection and organization of data, interdisciplinary model development, transparency of models, and visualization of the results. Neither purely mathematical nor purely experimental approaches will suffice to help us better understand the world we live in and shape so intensively.

Until recently, we needed significant preparation in mathematics and computer programming to develop such models. Because of this hurdle, many have failed to give serious consideration to preparing and manipulating computer models of the events and developments in the world around them. This book, and the methods on which it is built, will empower us to model and analyze the dynamics characteristic of economic processes and human–environment interactions.

Without computer models, we are often left to choose between two strategies. First, we may resort to theoretical models that describe the world around us. Mathematics offers powerful tools for such descriptions, adhering to logic and providing a common language by sharing similar symbols and tools for analysis. Mathematical models are appealing in social and natural science, where cause and effect relationships are confusing. These models, however, run the risk of becoming detached from reality, sacrificing realism for analytical tractability. As a result, these models are accessible only to the trained scientist, leaving others to “believe or not believe” the model results.

Second, we may manipulate real systems to understand cause and effect. One could modify the system experimentally (e.g., introduce a pesticide, some $CO_2$, etc.) and observe the effects. If no significant effects are noted, one is free to assume the action has no effect and increase the level of the system change. This is an exceedingly common approach. It is an elaboration of the way an auto mechanic repairs an engine, by trial and error. But social and ecological systems are not auto engines. Errors in tampering with these systems can have substantial costs, in both the short term and the long term, and can bring with them a series of other unintended and unanticipated consequences that may lead to more tampering, further errors, and so on. Despite growing evidence, the trial and error approach remains the meter of the day. We trust that, just like the auto mechanic, we will be clever enough to clear up the problems created by the introduced change. We let our tendency toward optimism mask the new problems.

However, the level of intervention in social and ecological systems has become so great that the adverse effects cannot be ignored. As our optimism about repair begins to crumble, we take on the attitude of patience toward the inevitable—unassignable cancer risk, global warming, fossil fuel depletion—the list is long. We are pessimistic about our ability to identify and influence cause and effect relationships. We need to understand the interactions of the components of dynamic systems in order to guide our actions. We need to add synthetic thinking to the reductionist approach. Otherwise, we will continue to be overwhelmed by details, failing to see the forest for the trees.

There is something useful that we can do to turn from this path. We can experiment using computer models. Models give us predictions of the short- and long-term outcomes of proposed actions. To do this we can effectively combine mathematical models with experimentation. By building on the strengths of each we will gain insight that exceeds the knowledge derived from choosing one method over the other. Experimenting with computer models will open a new world in our understanding of dynamic systems. The consequences of discovering adverse effects in a computer model are no more than ruffled pride.

Computer modeling has been with us for nearly 50 years. Why then are we so enthusiastic about its use now? The answer comes from innovations in software and powerful, affordable hardware available to every individual. Almost anyone can now begin to simulate real-world phenomena on his or her own, in terms that are easily explainable to others. Computer models are no longer confined to the computer laboratory. They have moved into every classroom, and we believe they can and should move into the personal repertoire of every educated citizen.

The ecologist Garrett Hardin and the physicist Heinz Pagels have noted that an understanding of system function, as a specific skill, needs to be and can become an integral part of general education. It requires the recognition (easily demonstrable with exceedingly simple computer models) that the human mind is not capable of handling very complex dynamic models by itself. Just as we need help in seeing bacteria and distant stars, we need help modeling dynamic systems. We do solve the crucial dynamic modeling problem of ducking stones thrown at us or safely crossing busy streets. We learned to solve these problems by being shown the logical outcome of mistakes or through survivable accidents of judgment. We experiment with the real world as children and get hit by hurled stones, or we let adults play out their mental model of the consequences for us and we believe them. These actions are the result of experimental and predictive models, and they begin to occur at an early age. In the complex social, economic, and ecological world, however, we cannot rely on the completely mental model for individual or especially for group action, and often we cannot afford to experiment with the system in which we live. We must learn to simulate, experiment, and predict with complex models.

In this book, we have selected the modeling software STELLA® with its iconographic programming style. Programs such as STELLA are changing the way in which we think. They enable each of us to focus and clarify the mental model we have of a particular phenomenon, to augment it, to elaborate it, and then to do something we cannot otherwise do: to run it, to let it yield the inevitable dynamic consequences hidden in our assumptions and the structure of the model. STELLA is not the ultimate tool in this process of mind extension. However, its relative ease of use makes the path to freer and more powerful intellectual inquiry accessible to every student.

These are the arguments for our book on *Dynamic Modeling of Natural Resource Use*. This volume was spurred by our first book on *Dynamic Modeling,* (Hannon and Ruth 1994) and others in the series on *Modeling Dynamic Systems*. The need to enhance our knowledge of human–environment interactions and the recognition that traditional teaching of economy–environment interactions frequently lacks tools that enable students to investigate, through an experimental approach, their own understanding of these interactions and to compare their findings against reality. We consider such modeling as the most important task before us. To help students learn to extend the reach of their minds in this unfamiliar yet very powerful way is the most important thing we can do.

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## Reference

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