Introduction: Understanding and Solving Environmental Problems in the 21st Century: Toward a new, integrated "hard problem science"

R. Costanza and S.E. Jørgensen

Existing social, economic, and political institutions, as well as academic disciplines, evolved at a time when natural resources and ecological services were vast relative to the human presence, and human impacts were relatively small and local in comparison. We have now moved from this relatively "empty world" to a world that is relatively full (Daly, 1992). In this new "full world", human impacts are more global and far-reaching, and the emphasis must shift from addressing problems in isolation to studying whole complex systems and the dynamic interactions between the parts. Complex systems are characterized by non-linearities, autocatalysis, complex, time delayed feedback loops, emergent phenomena, and chaotic behavior (Costanza et al., 1993; Kauffman, 1993; Patten and Jørgensen, 1995; Jørgensen, 1995). This means that the whole is significantly different from the simple sum of the parts, and scaling (the transfer of understanding across spatial, temporal, and complexity scales) is a core problem. Incorporating both biophysical and social dynamics makes these problems "wickedly complex" and difficult. They are impossible to address from within the confines of any single discipline.

To address these substantial challenges, we need to develop a new integrative approach to science, education, policy, and management that transcends existing disciplinary and other boundaries. We coined the term "hard problem science" (HPS) to refer to this new approach. It implies the following set of characteristics:

- **Consilience among all the sciences:** A balanced and pluralistic kind of "leaping together", in which the natural and social sciences and the humanities all contribute equitably, is needed. HPS needs to be truly transdisciplinary and multiscale, rather than either reductionist or holistic. One's discipline will be noted much as one's place of birth is noted today – where one started on life's journey, but not what totally defines one's life.

Understanding and Solving Environmental Problems in the 21st Century
Edited by R. Costanza and S.E. Jørgensen

- **A balance between synthesis and analysis:** HPS research and education need to balance analysis and synthesis to produce not just data, but knowledge and even wisdom. This will enable vastly improved links with social decisionmaking.
- **A pragmatic philosophy built on complex systems theory and modeling:** The limits of predictability of complex, adaptive, living systems need to be recognized, and a "pragmatic modeling" philosophy of science needs to be adopted. This will allow new, adaptive approaches to environmental management and better links with social decisionmaking.
- **A multiscale approach:** A multiscale approach to understanding, modeling, and managing complex, adaptive, living systems needs to be the norm, and methods for transferring knowledge across scales need to be vastly improved.
- **A consistent theory of cultural and biological co-evolution:** A consistent theory of biological and cultural co-evolution needs to evolve and increase understanding of human's place in nature and the possibilities of designing a sustainable and desirable human presence in the biosphere.
- **A recognition of the central role of envisioning in science:** Envisioning and goal setting need to be recognized as critical parts of both science and social decisionmaking. We need to create a shared vision of a desirable and sustainable future, and implement adaptive management systems at multiple scales in order to get us there.

The remainder of this book fleshes out these characteristics of HPS, around six core themes that structured discussion at the conference which formed the basis for this book (the "EcoSummit" – see the preface for more on the process). Following this introductory chapter, there are 12 additional chapters (two for each theme) plus a conclusions chapter summarizing the overall results. The first chapter in each theme is a background and overview of the theme. A first draft of this chapter was delivered by the working group chairs at the opening plenary session of the EcoSummit. It was edited based on further input from the working groups. The second chapter in each theme was drafted at the summit by each working group. It represents the general consensus of the working group (and the broader summit participants) on the issues brought up in the background chapters. Each working group consisted of 20 to 50 participants, who are listed under each consensus chapter. They communicated via email after the EcoSummit to finalize their consensus.

The six themes are:

(1) Integrated assessment and modeling (IAM)
(2) Complex, adaptive, hierarchical systems (CAHS)
(3) Ecosystem services (ES)
(4) Science and decisionmaking (SDM)
(5) Ecosystem health (EH) and human health
(6) Quality of life (QOL) and the distribution of wealth and resources

In keeping with the nature of the problems being addressed, the background and consensus chapters are complex, integrated, transdisciplinary, and interconnected with each other. Taken together, we believe that they provide the basis for understanding and solving environmental problems in the 21st century and beyond.

References

Costanza, R., Wainger, L., Folke, C. and Mäler, K.-G., 1993, Modeling complex ecological economic systems: toward an evolutionary, dynamic understanding of people and nature. BioSci. 43: 545–555.

Daly, H.E., 1992, Allocation, distribution, and scale: towards an economics that is efficient, just, and sustainable. Ecol. Econ. 6:185–193.

Jørgensen, S.E., 1995, The growth rate of zooplankton at the edge of chaos: ecological models. J. Theor. Biol. 175:13–21.

Kauffman, S., 1993, The Origins of Order: Self-Organization and Selection in Evolution (Oxford University Press, New York).

Patten, B.C. and Jørgensen, S.E., 1995, Complex Ecology: The Part–Whole Relationship in Ecosystems (Prentice Hall, Englewood Cliffs, NJ).