NAVIGATING SOCIAL–ECOLOGICAL SYSTEMS

In the effort towards sustainability, it has become increasingly important to develop new conceptual frames to understand the dynamics of social and ecological systems. Drawing on complex systems theory, this book investigates how human societies deal with change in linked social–ecological systems, and build capacity to adapt to change. The concept of resilience is central in this context. Resilient social–ecological systems have the potential to sustain development by responding to and shaping change in a manner that does not lead to loss of future options. Resilient systems also provide capacity for renewal and innovation in the face of rapid transformation and crisis. The term navigating in the title is meant to capture this dynamic process.

Navigating Social–Ecological Systems deliberately transcends academic disciplines, because the issues in focus require collaboration over the boundaries of the natural sciences, social sciences, and the humanities. Case studies and examples from several geographic areas, cultures, and resource types are included, merging forefront research from different disciplines into a common framework for new insights into sustainability.

FIKRET BERKES is Professor and former Director, Natural Resources Institute, University of Manitoba, Canada. He holds the Canada Research Chair in Community-Based Resource Management.

JOHAN COLDING is at the Centre for Research on Natural Resources and the Environment, Stockholm University, and the Beijer International Institute of Ecological Economics at the Royal Swedish Academy of Sciences, Stockholm, Sweden.

CARL FOLKE is Director of the Centre for Research on Natural Resources and the Environment (CNM), and a Professor in the Department of Systems Ecology, at Stockholm University, Sweden. He is also a Professor at the Beijer International Institute of Ecological Economics at the Royal Swedish Academy of Sciences, Stockholm, Sweden.

NAVIGATING SOCIAL–ECOLOGICAL SYSTEMS

Building Resilience for Complexity and Change

Edited by

FIKRET BERKES
The University of Manitoba, Winnipeg, Canada

JOHAN COLDING
The Royal Swedish Academy of Sciences, Stockholm, Sweden, and Stockholm University, Sweden

and

CARL FOLKE
Stockholm University, Sweden, and The Royal Swedish Academy of Sciences, Stockholm, Sweden

CAMBRIDGE UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, UK
40 West 20th Street, New York, NY 10011-4211, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

http://www.cambridge.org

First published 2003

Printed in the United Kingdom at the University Press, Cambridge

Typeface Times 10/13 pt *System* LaTeX 2ε [TB]

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Navigating social–ecological systems : building resilience for complexity and change /
edited by Fikret Berkes, Johan Colding, and Carl Folke.
p. cm.
Includes bibliographical references and index.
ISBN 0 521 81592 4
1. Social ecology – Congresses. I. Berkes, Fikret. II. Colding, Johan. III. Folke, Carl.
HM861 N38 2002
304.1–dc21 2002022268

ISBN 0 521 81592 4 hardback

Contents

Contributors

Janis B. Alcorn
World Resources Institute, Institutions and Governance Program, c/o 3508 Woodbine Street, Chevy Chase, MD 20815, USA

John Bamba
Institut Dayakologi, Jalan Budi Utomo, Block A3 No. 4, Pontianak 78241, West Kalimantan, Indonesia

Fikret Berkes
Natural Resources Institute, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

Kristen Blann
Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, 200 Hodson Hall, 1980 Folwell Avenue, St Paul, Minnesota 55108, USA

Lars Carlsson
Department of Political Science, Luleå University of Technology, 97187 Luleå, Sweden

Johan Colding
The Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Sweden, and Centre for Research on Natural Resources and the Environment, Stockholm University, S-106 91 Stockholm, Sweden

Iain J. Davidson-Hunt
Natural Resources Institute, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

Thomas Elmqvist
Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden

Carl Folke
Centre for Research on Natural Resources and the Environment and Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden, and The Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Sweden.

Madhav Gadgil
Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560012, India

Lance H. Gunderson
Department of Environmental Studies, Emory University, Atlanta, Georgia 30322, USA

Monica Hammer
Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden

C. S. (Buzz) Holling
16871 Sturgis Circle, Cedar Key, Florida 32625, USA

Anne Kendrick
Natural Resources Institute, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

Steve Light
Institute for Agriculture and Trade Policy, 2105 1st Ave S., Minneapolis, Minnesota 55404–2505, USA

Bobbi Low
School of Natural Resources and Environment, University of Michigan, Ann Arbor, Michigan 48109, USA

Stefanus Masiun
Jl. Boedi Utomo, Blk A-III/5, Komp. Bumi Indah Khatulistiwa, Pontianak, 78241, Kalimantan Barat, Indonesia

Jo Ann Musumeci
Three Oaks Research, 2606 Pleasant Ave. South, Minneapolis, Minnesota 55408–1441, USA

Ita Natalia
KpSHK (Consortium for Supporting Community Based Forest System Management) – NTFP Focal Point. Jl. Citarum Blok B X/23, Bogor Baru, Bogor 16152, Indonesia

Per Olsson
Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden

Elinor Ostrom
Center for the Study of Institutions, Population, and Environmental Change

(CIPEC), Indiana University, 513 North Park Street, Bloomington, Indiana 47408, USA

Antoinette G. Royo
The BSP-KEMALA, Ratu Plaza–17th Floor, Jalan Sudirman 9, Jakarta 10270, Indonesia

Cristiana S. Seixas
Natural Resources Institute, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

Carl Simon
Center for Study of Complex Systems, University of Michigan, Ann Arbor, Michigan 48109, USA

Maria Tengö
Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden

Ronald L. Trosper
College of Ecosystem Science and Management, Northern Arizona University, Flagstaff, Arizona, PO Box 15018, 86011–5018, USA

James Wilson
School of Marine Sciences, University of Maine, Orono, Maine 04469–5782, USA

Preface

It is evident that the dominant worldview in resource and environmental management of 'systems in equilibrium' is incompatible with observations of the complex dynamics of social and ecological systems. In the effort towards sustainability, it has become increasingly important to develop new conceptual frames to understand these dynamics. The framework underlying the book is complex systems theory, with the explicit objective of examining ways of building social–ecological resilience to enhance the capacity to deal with complexity and change. In particular, we look for effective ways of analyzing the phenomenon of change and how to respond to change in a manner that does not lead to loss of future options. The 14 chapters of the volume investigate how human societies deal with change in coupled social–ecological systems and build capacity to adapt to change. The term navigating in the title of the book is meant to capture this dynamic process.

It is an edited volume, but it is different from most edited volumes. We have used a common framework for the syntheses and the case-study analyses of a diversity of resource management systems. The chapters, written by scholars from several disciplines, have been developed on the basis of the common framework. The Introduction presents the framework and direction of the volume followed by four major sections: perspectives on resilience; building resilience in local management systems; social–ecological learning and adaptation; and cross-scale institutional response to change. In the final chapter we synthesize the lessons of the volume, emphasizing the need to learn to live with change and uncertainty; to nurture diversity for resilience; to combine different types of knowledge for learning about complex systems; and to create opportunity for self-organization towards social–ecological sustainability. The volume deliberatively transcends disciplinary boundaries, because the issues in focus require collaboration over the boundaries of the natural sciences, social sciences, and the humanities.

The work with the volume was initiated as a project of the Resilience Network, a research program of the Beijer International Institute of Ecological Economics in Stockholm, Sweden, and University of Florida, USA. We are forever indebted to C.S. (Buzz) Holling, the founder of the Resilience Network, to Karl-Göran Mäler, the Director of the Beijer Institute, and to the program director of the network, Lance Gunderson, who is also a chapter author of this volume, for providing support to our work on understanding the dynamics of social–ecological systems in the context of this 3-year research program.

The project, *Dynamics of Ecosystem–Institution Linkages for Building Resilience,* started in early 1998. Project members and potential chapter authors were sent an invitation, along with a Beijer Discussion Paper providing a tentative common framework for the project. Two workshops were held, the first in the fall of 1998 at the Beijer Institute in Stockholm, in which the framework and possible contributions were discussed and improved and chapter outlines constructed. Draft chapters were presented and discussed at a second workshop held in the fall of 1999 at the University of Manitoba, Winnipeg. In June 2000, many of the papers were presented at Indiana University at a conference of the International Association for the Study of Common Property (IASCP). The editors examined the second drafts, they were revised and sent for peer review in August/September 2000. Three or four scientific experts, two of them external to the project group, have reviewed each chapter. The work of the project and the production of the book have been a joint effort, and consequently the editorial author order is alphabetic.

Fikret Berkes, Johan Colding, and Carl Folke
Stockholm and Winnipeg
October 2001

Acknowledgements

There are many that have supported us during the work with this book. Special thanks go to the referees who reviewed the chapters. In addition to those who were also chapter authors, we are most grateful for the constructive comments by Alpina Begossi, Christo Fabricius, Clark Gibson, C.S. Holling, Gary Kofinas, Simon Levin, Robin Mearns, Nick Menzies, Richard Norgaard, Uygar Ozesmi, Kathryn Papp, P.S. Ramakrishnan, Steve Sanderson, John Sinclair, Nancy Turner, Paulo Vieira, Brian Walker, and Oran Young.

The content of the volume was strongly inspired by the work of the Resilience Alliance. Buzz Holling was instrumental in creating the alliance, now under the enthusiastic leadership of Brian Walker. Chapters of the book were discussed in meetings of the alliance, and we gratefully acknowledge the support of all of our exceptional colleagues at the Resilience Alliance for their fundamental role in providing inspiration and improving the content of the volume. We are also indebted to the valuable discussions and comments of our colleagues, Jan Bengtsson, Kristen Bingeman, Line Gordon, Don Ludwig, Phil Lyver, Fredrik Moberg, Magnus Nyström, Lowell (Rusty) Pritchard, and Max Troell.

We express our genuine thanks to Christina Leijonhufvud and Astrid Auraldsson of the Beijer Institute for their assistance with the Stockholm workshop, and to Anne Kendrick and Viviane Weitzner of the Natural Resources Institute, University of Manitoba, for the Winnipeg workshop. Thanks are due to Peter Vandeburg and Magnus Anderson for producing the illustrations, and to Amy Rader and Miriam Huitric for improving readability. The chapter authors deserve special thanks for their patience with several rounds of revising and refining manuscripts and handling numerous inquiries and comments from the editors.

The Dynamics of Ecosystem–Institution Linkages for Building Resilience project was supported by a grant from the John D. and Catherine T. MacArthur Foundation, which we gratefully acknowledge. The work of Johan Colding and

Carl Folke reported in this book was also supported by the Swedish Council for Planning and Coordination of Research (FRN), the Rockefeller Foundation, and the Swedish Man and the Biosphere Program with funds from the Swedish Research Council (Vetenskapsrådet). Fikret Berkes' work was supported by the Social Sciences and Humanities Research Council of Canada (SSHRC), and the project participation of the University of Manitoba researchers was supported by a grant from the Research Development Initiatives (RDI) program of the SSHRC.

Foreword: The backloop to sustainability

C.S. HOLLING

Introduction

I hazard a guess that people know enough about growth to know how to nurture it – mostly. But when growth stops or collapses, they do not know enough about protection or about novelty to know how to renew confidently for the next phase of growth. And they do not know how the two – growth and novelty – interact. As one consequence, economic forecasters, for example, do well in predicting rates of growth while on a growth path. They do a poor job at times of recession, or even worse at times of looming depression.

That is why I said 'mostly'. Growth of a cell or a society occurs gradually. It builds potential that accumulates slowly and it creates two conflicting attributes – increasing potential but also increasing vulnerability. Increase in potential roughly represents an increase in wealth represented in those structures that acquire, store, maintain and use potential. Increase in wealth gives potential for alternative futures. The increase in vulnerability comes from increase in structure that adds complexity but also vulnerability. As a consequence, eventually cells can die and societies can revolt. Growth then stops or reverses.

But cells and societies also reproduce and reinvent in the process of cyclic transformations. That is when evolution and deep changes are created. The bewildering, entrancing, unpredictable nature of nature and people, the richness, diversity and changeability of life come from that evolutionary dance generated by cycles of growth, collapse, reorganization, renewal and re-establishment.

We call that the adaptive cycle, as noted in Figure 1.2 in the introductory chapter, where its essential features are described. The 'front-loop' of that cycle is the loop of growth. The 'back-loop' is the loop of reorganization.

The editors of this book, Carl Folke, Fikret Berkes and Johan Colding, are interested in sustainable systems. Those are systems that persist, but also that evolve and change. Growth is important, but even more so are the forces in a healthy system that dominate during episodes when growth is halted or reversed,

when deep uncertainty explodes, when several alternative futures become suddenly perceived and unpredictability explodes. It is a time of crisis, but also of opportunity. Unexpected interactions can occur among previously separate properties that can nucleate an inherently novel and unexpected focus for future good or ill.

At such times, the future can also be suddenly shaped by externally triggered events such as those from slowly changing climate, from entrants of invasive species, from human immigrants driven by geopolitical changes or from unexpected terrorist events. Such apparently external events can launch future development along an unpredictable path.

During such times, uncertainty is high, control is weak and confused, and unpredictability is high. But space is also created for reorganization and innovation. It is therefore also a time when individual cells, individual organisms or individual people have the greatest chance of influencing events. There is opportunity with low costs of failure possible. The future can be mapped by experiments rather than by long-term plans. It is the time when a Gandhi or a Hitler can use events of the past to transform the future for great good or great ill. In a biological evolutionary setting, it is a time when mammals can replace dinosaurs as the dominant life form. It is the time of the 'Long Now' (Brand, 1999).

The editors therefore break a tradition in this book. They see that the essence of sustainability cannot be defined from metaphors of growth, equilibrium and stability. Rather it is defined from metaphors of novelty, memory and instability. They reverse existing traditions of exploration and analysis by focusing on the back-loop of collapse and reorganization, rather than on the front-loop of growth and predictability. They therefore focus on foundations for change. They focus on forces of evolution from biology, ecology, society and culture.

Their approach is integrative, merging the natural and social sciences. And they do that by choosing largely an analysis of existing contemporary and traditional societies around the world and by exploring the responses of such systems to crises and change. That focus emerged as one of the four central themes of the Resilience Project, a 5-year international project to develop integrative theory for sustainable systems and to propose integrative practice that can be tested within developed and developing regions.

The overall theories of the Resilience Project emerged from selecting, expanding and integrating existing theories in economics, ecosystem science, institutional research and adaptive complex system theory. The practice emerged from experience in regions where there is significant multiple use of renewable resources: agriculture, forestry, fisheries, rangeland grazing, wildlife and eco-tourism. Specifically, the regions included semi-arid grasslands and

savannas in Africa, Australia and North America, coral reefs in tropical regions, boreal forested regions in Canada, the USA and Europe, enclosed seas of the Baltic region of Europe and in south Florida, and wetlands of Wisconsin, Minnesota, Florida and Europe. The research has been an effort of synthesis through cooperation among a wonderful international group of scientists, scholars and practitioners, together with their students and collaborators.

This book is one of four that the project has created. One concerns nonlinear economics (Mäler and Starrett, in process) and the breakdown of traditional linear economics under certain conditions when resources are exploited in ecosystems. Another explores different large-scale ecosystems and identifies their structure and function (Gunderson and Pritchard, 2002), particularly the causes of multi-stable states and the surprises that result. Still another is the central integrative volume (Gunderson and Holling, 2002) that presents the integrative theory called panarchy. It is that theory that this book chooses as its base in its delightful examination of the structures formed by people and nature, particularly at times of fundamental crisis or transformation. Its message is therefore of deep significance at these times of national and international transformations in economics, society and security.

The terrorist attacks on September 11, 2001 in New York and Washington are the events that make this period one recognized as a time of crisis and transformation by the peoples of the world. But those events emerge from slower processes that have paced changes in development, politics and our natural endowments since the Second World War – locally and globally. This book and indeed all four of the books provide a foundation to develop and evaluate responses of nations and people to such profound changes. We do not do that here, because the terrorist events are so recent. But the shape of the influence of these works is becoming clearer, and will be the foundation for the next immediate target of thought and action. We encourage readers to do the same, enriching the effort with their own experiments in enquiry and invention.

The pathology of regional development

Our resilience work focused particularly on regions where local history and status interact with global and international processes. It was launched by the following pattern that was observed in several dozen examples of development and resource management policies initiated in both developed and developing nations (Gunderson, Holling and Light, 1995; Holling and Meffe, 1996). That pattern exposed an intriguing paradox in regions dominated by the 'modern' context of the developed nations since the Second World War. It consistently emerged as those regional systems experienced a crisis or policy change.

The Regional Resource and Development Pathology has the following features:

1. The new policies and development initially succeed in reversing the crisis or in enhancing growth.
2. Implementing agencies initially are responsive to the ecological, economic and social forces, but evolve to become narrow, rigid and myopic. They become captured by economic dependents and the perceived needs for their own survival.
3. Economic sectors affected by the resources grow and become increasingly dependent on perverse subsidies.
4. The relevant ecosystems gradually lose resilience to become fragile and vulnerable and more homogeneous as diversity and spatial variability are reduced.
5. Crises and vulnerabilities begin to become more likely and evident and the public begin to loose trust in governance.

In rich regions the result is spasmodic lurches of learning with expensive actions directed to reverse the worst of the consequences of past mistakes. An example is the present effort to restore the Everglades ecosystem in south Florida – the largest effort of restoration that has ever been attempted (Gunderson, 1999).

In poor regions the result is dislocation of people, increasing uncertainty, impoverishment and a poverty trap. Rarely, a radical new approach to development is invented that depends more on people's inventiveness and the transformation of strategic goals than on money. An example is the invention of community and economic utilization of biodiversity in Zimbabwe after the catastrophic droughts of the 1980s exposed the unsustainability of past development (Lynam, 1999). But that transformation is now being destroyed as its vulnerability to national political corruption is exposed.

Diagnosis of the pathology

Sustainable development and management of global and regional resources are not an ecological problem, nor an economic one, nor a social one. They are a combination of all three. And yet actions to integrate all three in the developed nations have short-changed one or more. Sustainable designs driven by conservation interests ignore the needs for an adaptive form of economic development that emphasizes individual enterprise and flexibility. Those driven by industrial interests act as if the uncertainty of nature can be replaced with human

engineering and management controls, or ignored altogether. Those driven by social interests act as if community development and empowerment alone can surmount any constraints of nature or of external forces. As investments fail, the policies of government, private foundations, international agencies and non-governmental organizations (NGOs) flop from emphasizing one kind of partial solution to another. Over the last three decades, such policies have flopped from large investment schemes, to narrow conservation ones, to equally narrow community development ones, to libertarian market solutions.

There has been lots of despair over failures but little benefit from the learning that has occurred. And little sharing of learning across regions.

Each spasm of policy change builds on theory, though many would deny anything but the most pragmatic and non-theoretical foundations to their proposed actions. The conservationists depend on theories of ecology and evolution, the developers on variants of free market models, the community activists on theories of community and social organization. All these theories are correct. Correct in the sense of being partially tested and credible representations of one, but only one, part of reality. The problem is that they are partial. Each misses a critical dimension. Economic theory deals poorly with slow variables that form cultural and ecological foundations for sustainability. Ecological theory ignores the richness of people's needs and inventiveness. Social theory is fragmented and static.

But our integrated theory has now been developed by a leading group of ecologists, economists and social scientists drawing upon extensive regional experience. It is a theory that recognizes the synergies and constraints among nature, economic activities, and people – a theory that informs and emerges from empirical practice.

Even the most ruthlessly pragmatic goals for developing policies and investments for sustainability need such a theoretical foundation that integrates ecological with economic with institutional with evolutionary theory – that overcomes the disconnect rooted in current theoretical limitations within each field. It is that integrative theoretical foundation and the practical consequences of it that have been the focus of the Resilience Project supported by The MacArthur Foundation. It is that integrative theory that was expanded by the discoveries in this book.

A prescription

The failures of the past have not been complete: there have been partial successes. This mixed picture comes because theories, trials and projects were not wrong, just too partial. The recent fad for community-based development

alone is another such correct, partial solution that will fail. The gales of change internationally (international financial contagion, migration, the emergence of the Internet), globally (climate change, ozone depletion, novel diseases) and regionally (conflicts and politics of sustainability, terrorism, biodiversity and resilience loss) create opportunity and a potential for constructive change. Now is the time to protect and integrate the good experience, ignore the bad and launch and communicate safe-fail experiments.

Oddly, the present recognition of global crises makes this the time to share the fruits of innovative development widely between North and South as it emerges, not just among those of the North or those of the South after it has in part failed. The Internet provides an arena to invent and communicate ways of learning and doing that are discovered in local regions around the world.

These gales of change suggest that the window for constructive change has opened at several scales. It is a time when conditions of the back-loop of the adaptive cycle dominate. Under those conditions, the elements of a prescription for facilitating constructive change are:

- Identify and reduce destructive constraints and inhibitions on change, such as perverse subsidies.
- Protect and preserve the accumulated experience on which change will be based.
- Stimulate innovation and communicate the results in a variety of safe-fail experiments that probe possible directions, in a way that are low in costs for people's careers and organizations' budgets.
- Encourage new foundations for renewal that build *and sustain* the capacity of people, economies and nature for dealing with change.
- Encourage new foundations to expand and communicate understanding of change.

Lessons that derive from exploration of these backloop studies include the expectation that dynamics of social–ecological systems will have multiple domains of attraction and that the system can flip from one to another, with large consequences for people (Berkes and Folke, 1998). The delightful simplified models of Carpenter and Brock show the consequences are real when integration is at the heart of the models (Carpenter, Brock, and Hanson, 1999). Resilience, multi-stable states, and learning about slow and spatially remote variables are revealed as a key to sustainability (Holling 2001). That is where the social–ecological memory plays a central role, as shown in several of the studies of this book. For some time prior to a domain flip, the impending collapse can be evident to some participants in the system and the system itself becomes an

accident waiting to happen. Breakdown is inevitable. After collapse, innovation and experimentation can be favoured. Participants find themselves asking how learning can be stimulated in ways that enhance sustainability. In the end, we find that we need to create excitement, identify options in the form of alternative visions of the future, and build hope.

References

Berkes, F. and Folke, C., eds. 1998. *Linking Social and Ecological Systems. Management Practices and Social Mechanisms for Building Resilience*. Cambridge: Cambridge University Press.

Brand, S. 1999. *The Clock of the Long Now*. New York: Basic Books.

Carpenter, S., Brock, W., and Hanson, P. 1999. Ecological and social dynamics in simple models of ecosystem management. *Conservation Ecology* 3(2): 4. www.consecol.org/vol3/iss2/art4

Gunderson, L.H. 1999. Resilience, flexibility and adaptive management – antidotes for spurious certitude? *Conservation Ecology* 3(1): 7 www.consecol.org/vol3/iss1/art7

Gunderson, L.H. and Holling, C.S., eds. 2002. *Panarchy: Understanding Transformations in Systems of Humans and Nature.* Washington DC: Island Press.

Gunderson, L.H., Holling, C.S., and Light, S.S., eds. 1995. *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. New York: Columbia University Press.

Gunderson, L.H. and Pritchard, L., eds. 2002. *Resilience and the Behavior of Large-Scale Ecosystems*. Washington DC: Island Press.

Holling, C.S. 2001. Understanding the complexity of economic, ecological and social systems. *Ecosystems* 4: 390–405.

Holling, C.S. and Meffe, G.K. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10: 328–37.

Lynam, T. 1999. Adaptive analysis of locally complex systems in a globally complex world. *Conservation Ecology* 3(2): 13. www.consecol.org/vol3/iss2/art13

Mäler, K.-G. and Starrett, D., eds. in process. *Ecological and Economic Modelling*.