

Graeme S. Cumming

Spatial Resilience in Social-Ecological Systems

 Springer

Spatial Resilience in Social-Ecological Systems

Graeme S. Cumming

Spatial Resilience in Social-Ecological Systems

 Springer

Graeme S. Cumming
Percy FitzPatrick Institute
DST/NRF Centre of Excellence
University of Cape Town
Rondebosch
7701 Cape Town
South Africa
graeme.cumming@uct.ac.za

The cover photograph shows a view from Strandfontein wastewater treatment works (near Muizenberg, on the edge of False Bay), looking towards Table Mountain. The idyllic appearance of this wetland disguises the high human use of this system and the ecological costs of the interaction: high *Escherichia coli* levels in the water in the settling ponds, invasive *Typha* reedbeds on the pond's edge, a landfill site just out of view to the left of the picture, and globally endangered lowland fynbos vegetation on the ridge behind the pond. Despite these problems, Strandfontein remains a nationally important site for waterbirds. Photograph by Graeme S. Cumming, 2008.

ISBN 978-94-007-0306-3

e-ISBN 978-94-007-0307-0

DOI 10.1007/978-94-007-0307-0

Springer Dordrecht Heidelberg London New York

© Springer Science+Business Media B.V. 2011

No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission from the Publisher, with the exception of any material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

*To Nils and Clara, my delightful
inspirations –*

*May you find as much pleasure as I have in
exploring this green world!*

Preface

This book represents a personal landmark along a path that I have been following for close to 15 years. Along the way I have spent considerable amounts of time debating and pondering with friends and colleagues over the relevance of space, and spatial variation, for the intricate workings of complex systems. These interactions have greatly enriched the journey, and I remain deeply grateful for them.

Thanks are due to many people. Although I can not list all of you here, I would particularly like to acknowledge the influence of three groups. The first consists of members of the Resilience Alliance, which has provided a wonderful arena for free thought and passionate debate. The Resilience Alliance has been the creation of many people who can not all be listed here, but my particular thanks go to Buzz Holling, Steve Carpenter, Carl Folke, Lance Gunderson, Phil Taylor, and Brian Walker for their role in consistently creating, redefining, and defending this small but highly influential think-space. Within the Resilience Alliance I am also deeply indebted to a group of younger scientists for crazy discussions and far-ranging debate: in this context, thanks are particularly due to Garry Peterson, Jon Norberg, Craig Allen, Marco Janssen, Marty Anderies, Örjan Bodin, Michael Schoon, and Henrik Ernstson.

The second important group of people is the roadies; an informal, interdisciplinary collection of academics and students at the University of Florida who met over the course of 4 years (and beyond) to discuss social-ecological resilience in the context of understanding the impacts of the transAmazon highway. From this group I would particularly like to thank Jane Southworth, Steve Perz, Grenville Barnes, Marianne Schmink, Mike Binford, Katie Sieving, and Bob Holt.

The third group consists of the many graduate students, now spread across different continents in various professional roles, who through their ideas, questions and uncertainties about spatial analysis have helped to highlight problem areas and clarify my thinking. Special thanks in this group are due to Lin Cassidy, Matt Child, Amy Daniels, Amy Duchelle, Simon Dures, Ann George, Grant Joseph, Matt Marsik, Mduduzi Ndlovu, Heidi Richter, Brian Spiesman, and Claudia Stickler.

This book owes its existence in part to Margaret Deignan of Springer SBM, who suggested the project and has proved a willing and supportive editor. Individual chapters have been greatly improved by the contributions of colleagues who took

on reviews of one or more chapters. Insightful and constructively critical comment was provided by Örjan Bodin, Matt Child, David Cumming, Henrik Ernstson, Eric Lambin, Harini Nagendra, Jon Norberg, Magnus Nystrom, Xanic Rondon, Jane Southworth, and Cathy Wilkinson. David Cumming deserves special mention for providing detailed input on six of the eleven chapters as well as providing several photographs; and Harini Nagendra, for offering invaluable big-picture comments on the entire book. Joshua Lewis kindly took a photograph of a floatable house for me, and I am further indebted to Steve Carpenter, Carl Folke and Bob Holt for their cover endorsements.

Writing this book has been a sabbatical project, and I am grateful to the University of Cape Town and the Oppenheimer Foundation for their financial support during the writing period. Additional assistance was provided by the Stockholm Resilience Centre and the Department of Systems Ecology at the University of Stockholm, with particular thanks to Thomas Elmqvist and Carl Folke for making our stay in Stockholm possible. I am also grateful to my parents, David and Meg, and to my wife's parents, Rolf and Elizabeth, for hosting us for periods in Zimbabwe and Germany respectively.

Finally, no set of acknowledgements would be complete without mention of my immediate family, who have supported me wholeheartedly in completing this book: my wife, Katharina; and my children, Nils and Clara, to whom this book is dedicated.

Cape Town, South Africa

Graeme S. Cumming

Contents

1	Introducing Spatial Resilience	1
	References	5
2	Conceptual Background on Social-Ecological Systems and Resilience	7
	Introduction	7
	Conceptual Foundations and Origins of SES Theory	7
	Defining Complex Systems and Spatial Resilience	9
	First, a Word About Clarity	9
	Getting Down to Definitions	10
	Higher-Order or Emergent System Properties	17
	Feedbacks, Thresholds, and Alternative Stable States	18
	What Is Spatial Resilience?	21
	Internal Elements of Resilience	22
	References	28
3	A Theoretical Framework for the Analysis of Spatial Resilience	35
	Introduction	35
	What Is Theory?	35
	Theoretical Frameworks for Analysing Social-Ecological Systems	37
	Developing and Working with a System Description	43
	Analysing Spatially Explicit Aspects of Resilience	46
	Operationalising the Framework	55
	Approach 1: Winnow Down	59
	Approach 2: Identity and Threshold Focus	60
	Approach 3: Add Space to a Simple Systems Model	60
	Approach 4: Use Scale and Scaling as Unifying Themes	61
	Approach 5: Use of Narratives	61
	Concluding Comments	61
	References	62

4	Introduction to Mechanistic Spatial Models for Social-Ecological Systems	67
	Introduction	67
	Challenges in Modelling Complex Systems	68
	Spatial Models in Ecology	75
	Foundations of Spatial Models	75
	Spatially Explicit Methods	77
	Concluding Comments	83
	References	83
5	Spatial Models in Ecology and Spatial Resilience	87
	Introduction	87
	Why Focus on Ecological Models?	87
	Generalities and Models	89
	The Importance of Individual System Components	89
	Interactions Between Components	97
	Scaling Relationships	103
	The Role of the Environment	106
	Disturbance Propagation and Its Interactions with System-Wide Properties	109
	Conclusions: General Principles for Spatial Resilience	112
	References	114
6	Spatial Resilience in Networks	121
	Introduction	121
	Three Spatial Applications of Network Analysis	126
	Social Networks in Space: The Importance of Bridging Organizations	127
	Economic Interactions and Spatial Games: Cooperation and the Prisoner's Dilemma in Network Applications	128
	Ecological Networks: Resilience of Endangered Species and Reserve Networks	132
	Network Analysis and Spatial Resilience	133
	References	139
7	Spatial Resilience and Landscape Analysis	143
	Introduction	143
	Landscapes as Complex Systems	148
	Landscapes as Complex <i>Adaptive</i> Systems	149
	Landscapes as a Unique Class of Systems	155
	Land Cover Maps as Populations of Pixels	157
	Landscapes and Spatial Resilience	164
	References	166

8 Spatial Resilience, Landscape Experiments, and Fragmentation 171

Introduction 171

Experimental Approaches to Spatial Processes in Ecology 172

 Different System Components Respond to Changes
 in Spatial Patterns and Processes Differentially 177

 Spatial Resilience at a Community Level Is Influenced
 by Local Components 179

 As Fragments and Communities Become Smaller,
 the Idiosyncracies of the Local Community Become More
 Important and the Consequences of Fragmentation Become
 Harder to Predict 179

 Patch Surroundings (Local Context, Matrix) Matter 181

 Landscapes that Appear Fragmented May Not Be
 Fragmented for All System Components 181

References 182

9 Spatial Resilience and Fragmentation in Social Systems 185

Introduction 185

Clarifying Fragmentation Concepts 185

Urban Geography and Planning 188

Social Capital and Social Exclusion 190

Conflict as a Spatial Process 195

Conclusions from Social Science for Spatial Resilience 197

Integrating Fragmentation Concepts Across Disciplines 198

References 199

10 Spatial Resilience in Case Studies of SESs 205

Introduction 205

Moving from Case Studies to Theory 206

Theory to Case Studies: General to Specific 214

Example 1: Spatial Influences on Fish Biodiversity 216

Example 2: Understanding the Impacts of Catchment
Morphology on Fish Population Dynamics 222

Example 3: Spatial Variation in the Resilience
of Ecosystem Function 224

Concluding Comments 226

References 227

11 Synthesis and Conclusions 231

Introduction 231

Where from? 232

Overarching Themes 235

Where to?	237
Theoretical Development	237
Methodological Development	238
Translational Development	240
Concluding Comments	243
References	244
Index	247