0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

Monitoring Ecological Impacts

Concepts and practice in flowing waters

Monitoring Ecological Impacts provides the tools needed by professional ecologists, other scientists, engineers, planners and managers to design assessment programs that can reliably monitor, detect and allow management of human impacts on the natural environment. The procedures described are well-grounded in inferential logic, and statistical models needed to analyse complex data are given. Step-by-step guidelines and flow diagrams provide the reader with clear and usable protocols, which can be applied in any region of the world and to a wide range of human impacts. In addition, real examples are used to show how the theory can be put into practice. Although the context of this book is flowing water environments, especially rivers and streams, the advice for designing assessment programs can be applied to any ecosystem.

Barbara J. Downes is a Senior Lecturer in Ecology in the School of Anthropology and Environmental Studies at the University of Melbourne, Australia. She is an aquatic ecologist, with research experience in upland streams and coastal marine environments.

Leon A. Barmuta is a Lecturer in Zoology at the University of Tasmania, Australia. He is a freshwater ecologist with extensive experience in basic and applied ecology in Australia and the United States of America.

Peter G. Fairweather is Professor of Marine Biology at the Flinders University of South Australia. He has worked in marine, estuarine and freshwater ecosystems in Australia and USA, and has edited the *Australian Journal of Ecology*.

Daniel P. Faith is a Principal Research Scientist at the Australian Museum, with research interests in systematics, biodiversity conservation and biological monitoring. He is an Associate Editor of *Systematic Biology*.

Michael J. Keough is a Reader in Zoology at the University of Melbourne. His research interests include the ecology of natural and human-induced disturbances in coastal habitats. He is co-author of *Experimental Design and Data Analysis for Biologists*, Cambridge University Press, 2002.

P. S. Lake is Professor in Ecology at Monash University, Australia. He is currently Chief Ecologist in the Cooperative Research Centre for Freshwater Ecology and is on the editorial board for *Freshwater Biology*.

Bruce D. Mapstone is a Senior Principal Research Fellow and Program Leader of the Sustainable Industries Program with the Cooperative Research Centre for the Great Barrier Reef World Heritage Area. He is based at James Cook University, Australia, and has research interests in tropical fisheries and their management and assessment of human impacts on natural systems.

Gerry P. Quinn is a Senior Lecturer in Biological Sciences at Monash University. He is an aquatic ecologist with interests in coastal marine habitats, and rivers and their floodplain wetlands. He is co-author of *Experimental Design and Data Analysis for Biologists*, Cambridge University Press, 2002.

Cambridge University Press 0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

Monitoring Ecological Impacts

Concepts and practice in flowing waters

BARBARA J. DOWNES University of Melbourne

LEON A. BARMUTA University of Tasmania

PETER G. FAIRWEATHER Deakin University

DANIEL P. FAITH The Australian Museum

MICHAEL J. KEOUGH University of Melbourne

P.S. LAKE Monash University

BRUCE D. MAPSTONE CRC Reef Research Centre and James Cook University

GERRY P. QUINN Monash University



© Cambridge University Press

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

> 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

© Downes 2002

This book is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2002 Reprinted 2003

Printed in the United Kingdom at the University Press, Cambridge

Typeface Swift 9/13pt System Poltype[®] [VN]

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

Library of Congress Cataloguing in Publication data

Assessing ecological impacts: applications to flowing waters/Barbara J. Downes ... [et al.]. p. cm. Includes bibliographical references (p.). ISBN 0 521 77157 9 1. Water quality biological assessment. 2. Stream ecology. I. Downes, Barbara J., 1958– QH96.8.B5 A76 2002 577.6'4'0287–dc21 2001043778

ISBN 0 521 77157 9 hardback

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

To Monty Python and the pursuit of Grails, holy or otherwise

and

To the noble but dying art of fellmongery

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

Contents

Preface and Acknowledgements

xi

Part 1	ľ
--------	---

	Intro	duction to the nature of monitoring problems and to river	:s 1	
1	Why we need well-designed monitoring programs			
	1.1	Human pressures on flowing waters	3	
	1.2	The need for this book	5	
	1.3	The scope, approach and intended audiences of this		
		book	7	
	1.4	The structure of the book and the purpose of each of		
		the chapters	9	
	1.5	Important issue	13	
2	The ecological nature of flowing waters			
	2.1	Rivers and their catchments	14	
	2.2	The biota of rivers and streams	18	
	2.3	Concepts of river structure and functioning	20	
	2.4	Issues of scale and patchiness in flowing waters	23	
	2.5	Important issues	26	
3	Assessment of perturbation			
	3.1	Types of disturbance	28	
	3.2	The purposes of monitoring	35	
	3.3	Important issues	42	
	Part I	1		
	Princ	iples of inference and design	43	
4	Infer	ential issues for monitoring	45	
	4.1	Sampling	47	
	4.2	Uncertainty and probability	48	
	4.3	Variables	54	

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

viii Contents

	4.4	Estimation	57	
	4.5	Statistical models	61	
	4.6	Analyses of variance (ANOVA)	76	
	4.7	Hypothesis-testing: classical approach	82	
	4.8	Hypothesis-testing: the Bayesian approach	94	
	4.9	Assumptions of statistical analyses of monitoring		
		programs	97	
	4.10	Univariate and multivariate analysis	105	
	4.11	Important issues	113	
5	The logical bases of monitoring design			
	5.1	Classes of monitoring	116	
	5.2	Monitoring to detect human impacts on the		
		environment	117	
	5.3	BACI designs	120	
	5.4	Scales of impact and monitoring	125	
	5.5	Careful design is the most important step	134	
	5.6	Important issues	134	
6	Problems in applying designs			
	6.1	A brief historical sketch	137	
	6.2	Problems inherent in the nature of rivers	142	
	6.3	Problems arising from the types of variables used	151	
	6.4	Social, institutional and political issues	158	
	6.5	Important issues	162	
7	Alternative models for impact assessment			
	7.1	Background of approaches	166	
	7.2	These approaches are different!	172	
	7.3	Formal sampling and analytical framework	174	
	7.4	Power considerations	188	
	7.5	Detecting more subtle effects	192	
	7.6	Extent of impacts	193	
	7.7	Flexible analysis/inflexible hypothesis	194	
	7.8	Important issues	194	
	Part 1	ш		
	Apply	ying principles of inference and design	195	
8	Appl	ying monitoring designs to flowing waters	197	
	8.1	Spatial variation and the location of controls	198	

Temporal variation, and Before and After sampling

8.2

224

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

			Contents	ix
	8.5	Important issues	247	
9	Infere	ential uncertainty and multiple lines of evidence	249	
	9.1	A brief revisit of inferential uncertainty and		
		probability	251	
	9.2	A levels-of-evidence approach	253	
	9.3	A suggested step-by-step guide to using a levels-of-		
		evidence approach	260	
	9.4	Some final comments on the process	286	
	9.5	Important issues	286	
10	Varia	bles that are used for monitoring in flowing waters	289	
	10.1	Considerations for choosing variables	298	
	10.2	Relative weighting of attributes	303	
	10.3	Important issues	305	
11	Defin	ing important changes	306	
	11.1	Why do we need to define changes in terms of 'effect	rt	
		sizes'?	306	
	11.2	Kinds of change, risks and consequences	310	
	11.3	Practical steps, and some difficulties, in setting an		
		effect size	314	
	11.4	Important issues	320	
12	Decis	ions and trade-offs	323	
	12.1	Making statistical decisions	323	
	12.2	Balancing Type I and Type II errors	326	
	12.3	5 0	336	
	12.4	Further variations on balanced decision-making	337	
	12.5	I	339	
13	-	nization	341	
	13.1	What we mean by optimization	341	
	13.2	5 5	341	
	13.3		343	
	13.4		345	
	13.5	5	347	
	13.6	Uncertainty in optimization	352	
	13.7	Post-monitoring 'optimization': implications for		
		decision criteria	353	
	13.8	A worked example – liming to decrease acidity of		
		streams	354	
	13.9	Important issues	366	
14	The s	pecial case of monitoring attempts at restoration	368	
	14.1	Issues concerning the study of ecological restoration		
	14.2	Can BACI designs be applied to ecological restoration	on? 370	

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

x Contents

15

	14.3	Analytical techniques applicable to restoration		
		monitoring	374	
	14.4	How long should we monitor attempts at restoration?	377	
14.5 The need for clarity in declaring the goals of				
		restoration	378	
	14.6	Important issues	380	
	What	at's next?		
	15.1	Links with management decisions as points of		
		negotiation	381	
	15.2	Changing monitoring objectives with progress in		
		understanding	383	
	15.3	Role of experiments in verifying mechanistic		
		understanding of an impact	383	
	15.4	How do we evaluate the effectiveness of a monitoring		
		program?	385	
	15.5	What research could complement monitoring		
		programs?	386	
	15.6	Reiterating the principles of this book	386	
	References			
	Index		421	

Cambridge University Press 0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

Preface and Acknowledgements

This book would not have been possible to write without a grant from xi The Land and Water Resources Research and Development Corporation (Canberra, Australia), awarded through its National River Health Program. We are grateful to both Dr Peter Davies (Director, NRHP) and Dr Nick Schofield (Program Manager – Water Resources) for their support for a fairly unusual project.

Various of our colleagues were asked to read and critique sections of the book. Thank you all for your candid and constructive criticism and for giving your opinions so freely. Your input made a difference:

Dr Kevin Cash (Environment Canada, Canada)

Dr Bruce Chessman (NSW Department of Land and Water Conservation, Australia)

Prof. David Dudgeon (University of Hong Kong, Hong Kong) Dr Rob Goudey (Victorian Environmental Protection Authority, Australia)

Dr Stuart Halse (WA Department of Conservation and Land Management, Australia)

Dr Chris Humphrey (NT Environmental Research Institute of the Supervising Scientist, Australia)

Dr Richard Marchant (Museum of Victoria, Australia)

Mr Leon Metzeling (Victorian Environmental Protection Authority, Australia)

Dr Steve Ormerod (Cardiff University, Wales)

Dr Vince Resh (University of California at Berkeley, USA)

Dr Mike Winterbourn (University of Canterbury, New Zealand)

We thank also an anonymous referee who commented on the entire manuscript and made many practical and valuable suggestions.

Steve Ormerod and David Bradley of the Catchment Research Group at Cardiff University made available data from a long-running experiment

0521771579 - Monitoring Ecological Impacts: Concepts and Practice in Flowing Waters Barbara J. Downes, Leon A. Barmuta, Peter G. Fairweather, Daniel P. Faith, Michael J. Keough, P. S. Lake, Bruce D. Mapstone and Gerry P. Quinn Frontmatter More information

xii Preface and Acknowledgements

in ecological restoration, which has been used as an example throughout this book. We thank them very much for making their data available to us, and for participating in e-mail discussions about their experiment.

PSL and GQ thank the CRC for Freshwater Ecology for financial support during some periods of writing. BJD thanks the Department of Biological Sciences at Monash University for providing a desk and writing space during a six-month sabbatical. Additionally, various people helped in the production of the manuscript: Chandra Jayasuriya and Andrew Hardie (School of Anthropology, Geography and Environmental Studies, University of Melbourne) drew or redrew the figures. Jim Thomson carried out substantial literature searches, and Leanne Matheson and Bill Dixon located some critical references. Alice King did much of the editing and formatting of the final manuscript, and Jodie Street assisted in compiling the final reference list. We are grateful to Alan Crowden (Cambridge University Press) for his support of the original book proposal and for considerable patience.

We thank numerous colleagues, partners, family members and friends – particularly Menna Jones and Gillian Napier – who have collectively provided generous support as well as, in some cases, being sounding-boards for some of the more controversial material.

Finally, a word about authorship. The structure, philosophy, content and opinions in this book arose largely from intensive debate among the authors during a series of three-day workshops. All chapters were shaped by our discussions and were co-written to some degree. As such, this is a truly collaborative, eight-authored book. The order of authorship does *not* indicate individual levels of contribution.