ADVANCING RIVER RESTORATION AND MANAGEMENT

Stream and Watershed Restoration

A Guide to Restoring Riverine Processes and Habitats

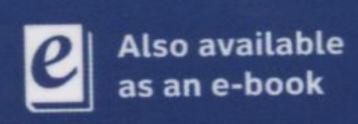
This book was born out of the clear need for a comprehensive resource for developing successful stream and watershed restoration plans and projects. It provides a systematic and adaptable approach for planning, prioritizing, implementing, and evaluating restoration at the regional, watershed, reach and project level. The reader will gain an understanding of stream and restoration ecology, methods for assessing watershed conditions and identifying restoration actions, different restoration techniques and their benefits and shortcomings, how to prioritize restoration actions, how to implement projects on the ground, and how to design a rigorous monitoring and evaluation program. It is organized in a stepwise fashion covering the key aspects of aquatic restoration including: assessing watershed and riverine processes and conditions, identifying restoration opportunities, choosing appropriate restoration techniques, prioritizing restoration actions, monitoring and implementation. It is intended as a guide for practitioners, an instructional manual for educators and students and a general reference for those interested in or active in the field of aquatic and restoration ecology.

Dr. Philip Roni has 25 years' experience working in and conducting research on streams and watersheds in North America and Europe. He has written and edited numerous papers and books as well as regional and international reports on stream and watershed restoration. He currently directs an interdisciplinary research program of more than 20 scientists working on fisheries, watershed and estuarine ecology and restoration at the Northwest Fisheries Science Center in Seattle, Washington.

Dr. Tim Beechie has more than 25 years of experience working in management and research of aquatic ecosystems, focusing on understanding how watershed and riverine processes influence channel morphology and river ecosystem dynamics. His recent publications focus on diagnosis of restoration needs through watershed analysis and development of process-based strategies for river restoration. He currently directs a team of scientists researching the influences of watershed processes and land uses on riverine ecosystems.



A companion website with additional resources is available at www.wiley.com/go/roni/streamrestoration







List of	Contributors, xi
Forew	ord, xiii
Series	Foreword, xv
Prefac	e, xvi
Introd	uction to Restoration: Key Steps for Designing Effective Programs arets. 1
1.1	Introduction, 1 What is restoration?, 2 Why is restoration needed?, 3 History of the environmental movement, 4 History of stream and watershed restoration, 5 Key steps for planning and implementing restoration, 7
1.7	References, 8
	rshed Processes, Human Impacts, and Process-based Restoration, 11
2.1 2.2 2.3	Introduction, 11 The hierarchical structure of watersheds and riverine ecosystems, 13 The landscape template and biogeography, 17
2.4	Watershed-scale processes, 18 2.4.1 Runoff and stream flow, 18 2.4.2 Erosion and sediment supply, 20 2.4.3 Nutrients, 22
2.5	Reach-scale processes, 22 2.5.1 Riparian processes, 22
	 2.5.2 Fluvial processes: Stream flow and flood storage, 26 2.5.3 Fluvial processes: Sediment transport and storage, 27 2.5.4 Channel and floodplain dynamics, 28 2.5.5 Organic matter transport and storage, 29 2.5.6 Instream biological processes, 29
2.6	Common alterations to watershed processes and functions, 31 2.6.1 Alteration of watershed-scale processes, 31 2.6.2 Alteration of reach-scale processes, 34 2.6.3 Direct manipulation of ecosystem features, 35
2.7	Process-based restoration, 35 2.7.1 Process-based principles for restoration, 36 2.7.2 Applying the principles to restoration, 37

Summary, 40

References, 40

2.8

2.9

3.1	Introdu	ction, 50
3.2	The role	e of restoration goals in guiding watershed assessments, 51
	3.2.1	Stating restoration goals, 52
	3.2.2	Designing the watershed assessment to reflect restoration goal
2.2		and local geography, 53
3.3		ng causes of habitat and biological degradation, 56
	3.3.1	Use of landscape and river classification to understand the watershed template, 57
	3.3.2	Assessing watershed-scale (non-point) processes, 61
		3.3.2.1 Sediment supply: Erosion and delivery to streams, 61
		3.3.2.2 Hydrology: Runoff and stream flow, 63
		3.3.2.3 Nutrients and pollutants, 68
	3.3.3	Assessing reach-scale processes, 70
		3.3.3.1 Riparian processes, 70
		3.3.3.2 Floodplain processes, 73
		3.3.3.3 Fluvial processes and conditions, 73
3.4	Assessi	ng habitat alteration, 79
	3.4.1	Habitat type and quantity, 79
	3.4.2	Water quality, 84
3.5	Assessi	ng changes in biota, 86
		Single-species assessment, 86
	3.5.2	Multi-species assessment, 89
3.6		ng potential effects of climate change, 91
3.7	Identify	ing restoration opportunities, 93
	3.7.1	Summarize the watershed assessment results and identify
		restoration actions, 93
	3.7.2	Develop a restoration strategy, 94
	3.7.3	Summarize constraints on restoration opportunities, 95
	3.7.4	Climate change considerations, 96
3.8		tudies, 96
		Skagit River, Washington State, USA, 96
	3.8.2	River Eden, England, UK, 100
	Summa	
3.10	Referer	nces, 104
The H	luman D	Dimensions of Stream Restoration: Working with Diverse Partne
to De	velop ar	nd Implement Restoration, 114
4.1	Introdu	iction, 114
4.2	Setting	the stage: Socio-political geography of stream restoration, 116
	4.2.1	Nature of the challenge, 116
	4.2.2	Understanding property and property rights, 116
	4.2.3	Landscapes of restoration, 117
	4.2.4	Understanding landowner/manager and agency objectives, 120
	4.2.5	Why understanding socio-political geography is important, 121
4.3	How st	tream restoration becomes accepted, 122
	4.3.1	Restoration as innovation, 123
	4.3.2	Innovation diffusion through networks, 123

Process of innovation adoption, 123

Why understanding innovation diffusion is important, 125

Innovation acceptance, 124

4.3.3

4.3.4

4.3.5

Watershed Assessments and Identification of Restoration Needs, 50

4.4	Organi them,	zations and the behaviors and motivations of those who work for
	4.4.1	Organizational behaviors and motivations, 126
		4.4.1.1 Motivations of officials, 126
		4.4.1.2 Leveraging organizational behaviors, 126
	442	Understanding your own and other organizations, 127
	4.4.3	Why understanding organizational patterns is important, 129
4.5		ches to elicit cooperation, 132
1.5		Institutions to support stream restoration, 132
		Techniques to engage landowners, 133
	4.5.3	Achieving agreement with project partners, 136
		4.5.3.1 The Prisoner's Dilemma, 136
		4.5.3.2 Guidelines to build and maintain cooperation, 136
	4.5.4	Why understanding cooperation is important, 138
4.6		g forward: Further reading in human dimensions of stream
		tion, 139
		Collective action, 139
		Social capital and the triple bottom line, 139
		Environmental justice, 140
		Resilience, 140
4.7		ary, 140
4.8		nces, 141
Selec	cting App	propriate Stream and Watershed Restoration Techniques, 144
5.1		uction, 144
	5.1.1	Common categories of techniques, 144
	5.1.2	
		be restored or improved?, 146
5.2	Conne	ctivity, 147
	5.2.1	Longitudinal connectivity, 147
		5.2.1.1 Dam removal and modification, 147
		5.2.1.2 Culvert and stream-crossing removal, replacement or modification, 149
		5.2.1.3 Fish passage structures, 151
	5.2.2	Techniques to restore lateral connectivity and floodplain
		function, 152
		5.2.2.1 Levee removal or setbacks, 152
		5.2.2.2 Reconnecting isolated floodplain wetlands, sloughs, an other habitats, 153
5.3	Sedime	ent and hydrology, 154
	5.3.1	Reducing sediment and hydrologic impacts of roads, 154
		5.3.1.1 Forest and unpaved road removal and
		restoration, 154
		5.3.1.2 Road improvements, 155
		5.3.1.3 Reducing or eliminating impacts of paved roads and
		impervious surfaces, 157
	5.3.2	Reducing sediment and pollutants from agricultural
		lands, 158
	5.3.3	Increasing sediment supply, retention and aggrading incised
		channels, 160
	5.3.4	Increasing instream flows and flood pulses, 160

5.4	Riparia	n restorat	ion strategies, 161
	5.4.1	Silvicult	ure techniques, 161
		5.4.1.1	Planting, 161
		5.4.1.2	Thinning to promote tree and vegetation growth, 164
			Removal of exotic and invasive species, 164
	5.4.2		and grazing reduction, 165
	5.4.3		buffers and protection, 167
5.5	Habitat		ment and creation techniques, 167
			n habitat improvement techniques, 167
			Structures to create pools, riffles, and cover and improve
		3.3.1.1	complexity, 168
		5512	Gravel addition and creation of spawning habitat, 171
			Recreating meanders, 171
	552		of floodplain habitats, 172
56			re habitat improvement techniques appropriate?, 173
5.6			storation techniques, 173
			restoration or control, 174
			abilization, 174
	5.6.3		additions, 175
	5.6.4		ion management, 176
	5.6.5		actors to consider when selecting restoration techniques,
		177	
5.7	Summa		
5.8	Referer	ices, 179	
Priorit	tization	of Waters	heds and Restoration Projects, 189
6.1		ction, 189	
6.2			Il goals and scale, 190
	6.2.1		ameworks, funding, and goals, 192
			and temporal scale, 192
6.3			ze projects? Selecting the team, 194
6.4			roaches and criteria, 194
0.1			n prioritization strategies, 195
	0. 1. 1		대한 경우를 보고 있는데 이번에 살아갔다. 이번에 가는 이번에 가는 이번에 있는데 보고 있는데 보고 있는데 보고 있
			Prioritizing restoration actions by project type, 195 Refugia, 195
			Habitat area and increase in fish or other biota, 199
		0.4.1.4	Capacity and life-cycle models for prioritizing habitats, 199
		6115	
			Costs, cost-effectiveness, and cost-benefit analysis, 201
		0.4.1.6	Conservation planning software and computer models, 203
		6117	Scoring and multi-criteria decision analysis, 204
	642		g a prioritization approach, 206
6.5			
			yses and examining rankings, 207
6.6	Summa		
6.7	Keleren	ices, 210	
Devel	oping, D	esigning,	and Implementing Restoration Projects, 215
		ction, 215	
7.2	Identify	the prob	lem, 217
7.3			ntext, 218
	The second secon		

	7.4		project goals and objectives, 219			
	7.5		gative analysis, 221			
		7.5.1	Investigative analyses for in-channel restoration projects, 221			
			7.5.1.1 Maps and surveys, 221			
			7.5.1.2 Hydrologic investigation, 223			
			7.5.1.3 Hydraulic modeling, 227			
			7.5.1.4 Sediment transport analysis, 230			
			7.5.1.5 Geomorphic investigation, 231			
			7.5.1.6 Geotechnical assessment, 232			
			7.5.1.7 Uncertainty and risk, 233			
		7.5.2	Investigative analyses for other restoration actions, 234			
	7.6	Evaluat	e alternatives, 235			
	7.7	Project design, 236				
		7.7.1	Design approaches, 237			
		7.7.2	Specify project elements that will meet project objectives, 238			
		7.7.3	Establish design criteria for project elements that define			
			expectations, 238			
		7.7.4	Develop design details to meet criteria for each element, 239			
		7.7.5	Verify that elements address project objectives, 239			
			Communicating project design, 239			
			7.7.6.1 Design reports, 240			
			7.7.6.2 Plans and specifications, 240			
	78	Implem	entation, 241			
			ring, 242			
			udies, 242			
	7.10					
			Removal of the Number 1 Dam, Chichiawan River, Taiwan, 243			
			Bridge Creek riparian restoration, 245			
	711		Fisher Slough Restoration, Skagit River, Washington, USA, 245			
		Summa				
	7.12	Keleleli	ices, 249			
8	Moni	toring an	nd Evaluation of Restoration Actions, 254			
	8.1					
	0.1	Introdu	ction, 254			
	8.2		ction, 254			
		What is	ction, 254 monitoring and evaluation?, 255			
	8.2	What is	ction, 254 monitoring and evaluation?, 255 or developing an M&E program, 256			
	8.2	What is Steps for 8.3.1	ction, 254 monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256			
	8.2	What is Steps for 8.3.1	ction, 254 monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259			
	8.2	What is Steps for 8.3.1	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261			
	8.2	What is Steps for 8.3.1 8.3.2	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263			
	8.2	What is Steps for 8.3.1 8.3.2 8.3.3	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263 Parameters: Determining what to monitor, 264			
	8.2	What is Steps for 8.3.1 8.3.2 8.3.3	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263 Parameters: Determining what to monitor, 264 Determining how many sites or years to monitor, 269			
	8.2	What is Steps for 8.3.1 8.3.2 8.3.3	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263 Parameters: Determining what to monitor, 264 Determining how many sites or years to monitor, 269 Sampling scheme, 272			
	8.2	What is Steps for 8.3.1 8.3.2 8.3.3 8.3.5 8.3.6 Guidelin	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263 Parameters: Determining what to monitor, 264 Determining how many sites or years to monitor, 269 Sampling scheme, 272 nes for analyzing and summarizing data, 273			
	8.2	What is Steps for 8.3.1 8.3.2 8.3.4 8.3.5 8.3.6 Guidelin Monitor	ction, 254 s monitoring and evaluation?, 255 or developing an M&E program, 256 Defining restoration goals and monitoring objectives, 256 Defining questions, hypotheses, and spatial scale, 257 8.3.2.1 Defining the spatial scale, 259 Selecting the monitoring design, 260 8.3.3.1 Treatments, controls, and references, 260 8.3.3.2 Before-after and before-after control-impact designs, 261 8.3.3.3 Post-treatment designs, 261 8.3.3.4 Which design is most appropriate?, 263 Parameters: Determining what to monitor, 264 Determining how many sites or years to monitor, 269 Sampling scheme, 272			

Summary, 275 8.7 References, 276 8.8 9 Synthesis: Developing Comprehensive Restoration Programs, 280 Introduction, 280 9.1 Components of a comprehensive restoration program, 280 9.2 Goals, assessments, and identifying restoration actions, 282 9.2.1 Prioritizing restoration actions or watersheds, 282 9.2.2 9.2.3 Selecting restoration techniques and designing restoration actions, 282 Monitoring, 283 9.2.4 Examples of bringing the components together, 284 9.2.5 Developing proposals and evaluating projects for funding or permitting, 9.3 286 Moving from opportunistic to strategic restoration, 287 9.4 Conclusions, 289 9.5

Index, 290

9.6

See Colour plate Section between 160-161

References, 289