

Contents

Contributors *xiii*

Foreword *xvii*

Preface *xxi*

Part I Spatial Patterning in the Sea *1*

1 Introducing Seascape Ecology *3*

Simon J. Pittman

1.1 Introduction *3*

1.2 Landscape Ecology and the Emergence of Seascape Ecology *4*

1.3 What is a Seascape? *6*

1.3.1 The Patch-Matrix and Patch-Mosaic Models of Seascape Structure *8*

1.3.2 The Spatial Gradient Model of Seascape Structure *11*

1.3.3 Combining Spatial Gradients and Patch Mosaics *12*

1.3.4 Chemical Seascapes and Ocean Soundscapes *13*

1.4 Why Scale Matters in Seascape Ecology *14*

1.5 Seascape Ecology can Inform Marine Stewardship *16*

1.6 Conclusions and Future Directions *18*

References *19*

2 Mapping and Quantifying Seascape Patterns *27*

Bryan Costa, Brian K. Walker and Jennifer A. Dijkstra

2.1 Introduction *27*

2.2 Defining Seascape Applications *30*

2.3 Identifying Scales for Seascape Mapping *31*

2.4 Sensor Selection for Seascape Mapping *32*

2.4.1 Passive and Active Sensors *33*

2.4.2 Environmental Conditions Limiting Passive and Active Sensors *35*

2.5 Representing Patterns in Seascape Maps *36*

2.5.1 The Continuous Gradient Concept *37*

2.5.2 The Patch-Mosaic Model *40*

2.5.3 Spatial Surrogates (Proxies) *42*

2.6 Quantifying Seascape Structure *43*

2.6.1	Sensitivity to Scale	43
2.7	Applications of Seascape Maps and Spatial Pattern Metrics	45
2.7.1	Understanding Uncertainty in Seascape Maps	47
2.8	Conclusions and Future Research Priorities	47
	References	48
3	Pelagic Seascapes	57
	<i>Kylie L. Scales, Diego Alvarez-Berastegui, Clare Embling and Simon Ingram</i>	
3.1	Introduction	57
3.2	Pattern and Process in the Pelagic Realm	58
3.2.1	Broad-scale Biogeographic Provinces	58
3.2.2	Finer Scale Patchiness and Patch Dynamics	61
3.2.3	Ecoclines and Ecotones in Pelagic Seascapes	62
3.2.4	Beneath the Surface: the Vertical Dimension of Pelagic Seascapes	64
3.3	Spatial Pattern Metrics for Pelagic Seascapes	66
3.3.1	Patch Mosaic Metrics	67
3.3.2	Surface Model Metrics – Identifying Ecoclines and Ecotones	67
3.3.3	Lagrangian Approaches	69
3.4	Spatial Ecoinformatics in the Pelagic Realm: from Physics to Predators	71
3.4.1	Broad-scale Migrations across Pelagic Seascapes	71
3.4.2	Linking Animal Movements to the Spatial Patterning of Pelagic Seascapes	72
3.4.3	Incorporating the Vertical Dimension in Spatial Ecoinformatics	73
3.5	Conclusions and Future Research Priorities	74
3.6	Glossary	75
	References	76
4	Scale and Scaling in Seascape Ecology	89
	<i>David C. Schneider</i>	
4.1	Introduction	89
4.1.1	The Development of the Concept of Scale in the Twentieth Century	90
4.1.2	Prevalence and Usage of 'Scale' in the Scientific Literature	91
4.1.3	Definition of Scale	93
4.2	Expressions of Scale	94
4.2.1	Graphical Expression of Scale	94
4.2.2	Graphical Expression of Scale in Research Planning	96
4.2.3	Formal Expression of Scale: Scope, Similarity and Power Laws	99
4.2.4	Scaling Manoeuvres	101
4.2.5	Ratio of Rates in Research Planning	103
4.3	Spatial and Temporal Scaling in Estimating Uncertainty	106
4.4	Spatial and Temporal Scaling in the Pelagic and Benthic Realms	107
4.5	Looking to the Future: Scaling Concepts and Practice in Seascape Ecology	108

- 4.5.1 From Useful Fictions to Calculation 108
- 4.5.2 From Comparative to Confirmatory Modes of Investigation 108
- 4.5.3 From Hypothesis Testing to Likelihood 110
- 4.5.4 From Scaling on a Mosaic to Scaling on the Continuum 111
- 4.6 From *Ceteris Paribus* to Dimensional Thinking 111
- 4.7 Acknowledgements 112
- References 112

Part II Linking Seascape Patterns and Ecological Processes 119

- 5 Ecological Consequences of Seagrass and Salt-Marsh
Seascape Patterning on Marine Fauna 121
Christoffer Boström, Simon J. Pittman and Charles Simenstad
- 5.1 Introduction 121
- 5.1.1 Seagrasses and Salt Marshes: Global Distributions and Ecosystem
Functions 122
- 5.2 Structural Processes and Change in Coastal Seascapes 122
- 5.2.1 Processes Creating and Maintaining Seagrass Seascapes 125
- 5.2.2 Processes Creating and Maintaining Salt-Marsh Seascapes 125
- 5.2.2.1 Tidal Channel Networks in Salt Marshes 128
- 5.3 Ecological Consequences of Seascape Structure 128
- 5.3.1 Seagrass Patch-size Effects on Epifauna and Fish 128
- 5.3.2 Patch Edges: Conceptual Framework and Application 130
- 5.3.2.1 Seagrass Edge Effects on Faunal Recruitment and Distribution 132
- 5.3.3 Effects of Salt-Marsh Patch Size, Edges and Connectivity on Faunal
Patterns and Processes 133
- 5.3.4 Faunal Linkages between Salt Marshes and Seagrass Meadows 135
- 5.4 Challenges and Opportunities in Seascape Ecology 138
- References 140
- 6 Seascape Patch Dynamics 153
Emma L. Jackson, Rolando O. Santos-Corujo and Simon J. Pittman
- 6.1 Introduction 153
- 6.2 From Patch Dynamics to Seascape Ecology 155
- 6.3 Scale 158
- 6.4 Factors Influencing Seascape Patchiness 160
- 6.5 Mapping and Quantifying Seascape Change 163
- 6.5.1 Habitat Mapping for Change Analysis 164
- 6.5.2 Characterization of Spatial Patterns 166
- 6.5.2.1 Continuous Metrics and Surface Analysis 167
- 6.5.2.2 Metrics, Scale and Sensitivity Analysis 168
- 6.5.2.3 Quantifying Seascape Change 168
- 6.5.3 Seascape Habitat Loss versus Fragmentation 170
- 6.5.4 Seascape Modelling 173
- 6.6 The Future of Seascape Dynamics Research 175
- References 177

7	Animal Movements through the Seascape: Integrating Movement Ecology with Seascape Ecology 189
	<i>Simon J. Pittman, Benjamin Davis and Rolando O. Santos-Corujo</i>
7.1	Introduction 189
7.1.1	Why Animal Movement is Central to Seascape Ecology 191
7.1.2	Advances in Movement Ecology and its Application in Marine Systems 193
7.1.3	Tracking and Mapping Capabilities 194
7.2	Using Animal Movements to Scale Ecological Studies 196
7.2.1	Building Movement Scales into Conceptual and Operational Frameworks 199
7.2.1.1	Component 1: Build a Conceptual Model 199
7.2.1.2	Component 2: Selecting Scale 199
7.2.1.3	Component 3: Tools Identification 201
7.3	Advances in the Visualisation and Quantification of Space-use Patterns 201
7.3.1	Estimating and Mapping Utilisation Distributions 201
7.3.2	Analysing Spatiotemporal Utilisation Patterns 204
7.3.3	Visualizing Movement Patterns across Three Spatial Dimensions 206
7.4	Linking Animal Movement Patterns to Seascape Patterns 208
7.4.1	Linking Individual Movement Trajectories to Seascape Structure 209
7.4.2	Individual Movement and Seascape Connectivity 211
7.4.3	Linking Species Interactions and Physiology with Movements across Seascapes 212
7.4.4	Experimental Seascapes to Investigate Animal Response to Seascape Patterns 214
7.4.5	Mechanistic Models 215
7.5	Implications of Animal-Seascape Understanding for Marine Stewardship 215
	References 217
8	Using Individual-based Models to Explore Seascape Ecology 229
	<i>Kevin A. Hovel and Helen M. Regan</i>
8.1	Introduction 229
8.1.1	What are IBMs? 229
8.2	Why use IBMs to Study Seascape Ecology? 231
8.2.1	The Effects of Habitat Structure on Populations are Consequences of Organismal Behavior 231
8.2.2	IBMs Allow for Extensive Manipulation of Seascapes 235
8.2.3	IBMs can be Used to Test for Ecological Effects of Habitat Configuration versus Habitat Amount 239
8.2.4	IBMs Allow Tests of How Seascape Change Influences Ecological Processes 241
8.2.5	IBMs Allow the Coupling of Processes Operating over Different Scales 245

- 8.3 Data for Parameterizing Seascape Ecology IBMs 246
- 8.3.1 Parameterization 246
- 8.3.2 Movement and Habitat Selection 247
- 8.3.3 Seascape and Habitat Structure 248
- 8.3.4 Other Factors 249
- 8.4 Challenges and Future Directions in Using IBMs to Explore
Seascapes 249
- References 251

Part III Seascape Connectivity 259

- 9 Connectivity in Coastal Seascapes 261
*Andrew D. Olds, Ivan Nagelkerken, Chantal M. Huijbers, Ben L. Gilby, Simon
J. Pittman and Thomas A. Schlacher*
- 9.1 Introduction 261
- 9.2 Global Synthesis of Connectivity Research 261
- 9.2.1 Research Theme 263
- 9.2.2 Geographical Distribution 264
- 9.2.3 Biological and Functional Consequences 266
- 9.2.4 Connectivity is Scale Dependent 267
- 9.3 Quantifying Connectivity: Advances in Key Tools and
Techniques 268
- 9.3.1 Tags and Telemetry 268
- 9.3.2 Ecogeochemical Markers 269
- 9.3.3 Genetics 269
- 9.4 Application of Seascape Connectivity to Coastal Seascapes: Focal
Topics 270
- 9.4.1 Focal Topic 1: Fish Movements Connecting Tropical Coastal
Seascapes 270
- 9.4.2 Focal Topic 2: Connectivity across the Land-Sea Interface 273
- 9.5 Integrating Connectivity into Marine Spatial Planning 275
- 9.6 Conclusions and Future Research Priorities 279
- References 280
- 10 Networks for Quantifying and Analysing Seascape
Connectivity 293
Eric A. Treml and Johnathan Kool
- 10.1 Introduction 293
- 10.1.1 Structural Connectivity 295
- 10.1.2 Functional Connectivity 296
- 10.1.3 Realised Connectivity 296
- 10.2 Network Models of Connectivity: Representing Pattern and
Process 297
- 10.2.1 Defining Nodes and Links 297
- 10.3 Modelling Marine Population Connectivity 300
- 10.3.1 Empirical Estimates of Marine Population Connectivity 301
- 10.4 Network Analysis of Marine Population Connectivity 303

10.4.1	Node and Neighbourhood-level Metrics	305
10.4.2	Components, Subgraphs and Clusters	306
10.4.3	Graph-level Metrics	306
10.4.4	Insights from Classic Networks	307
10.4.5	Planar Networks	308
10.4.6	Random Networks	308
10.4.7	Scale-free Networks	308
10.4.8	Small-world Networks	309
10.5	Case Study in Marine Connectivity: Hawaiian Islands	309
10.6	Conclusions and Future Research Priorities	312
10.7	Acknowledgements	313
	References	313
11	Linking Landscape and Seascape Conditions: Science, Tools and Management	319
	<i>Kirsten L. L. Oleson, Kim A. Falinski, Donna-marie Audas, Samantha Coccia-Schillo, Paul Groves, Lida Teneva and Simon J. Pittman</i>	
11.1	Introduction	319
11.2	Landscape Ecology as a Guiding Framework for Integrated Land-Sea Management	322
11.3	Modelling and Evaluating the Connections between Land and Sea	324
11.3.1	Measuring Threat Exposure from Land-based Sources	324
11.3.2	Spatial Modelling of Land-Sea Processes	325
11.3.2.1	Spatial Proxies	325
11.3.2.2	Hydrological Models	325
11.3.2.3	Nearshore Dynamics	326
11.3.2.4	Ecological Response and Social-Ecological Systems Models	327
11.3.3	Decision Analysis and Support	329
11.4	Case Studies	330
11.4.1	Hawai'i	330
11.4.1.1	Estimating Spatial Patterns of Erosion from Land Cover Change and Exposure of Reefs in Maui	331
11.4.2	Caribbean	334
11.4.2.1	Summit to Sea Runoff Modelling for St John, US Virgin Islands	334
11.4.2.2	Land-sea Decision Support Modelling for the Northeast Marine Corridor, Puerto Rico	336
11.4.3	Australia	339
11.4.3.1	Edgecumbe Bay Receiving Waters (Gregory and Eden Lassie Creek Sub-basins)	342
11.5	Towards Applying Landscape Ecology to Land-Sea Modelling and Management	347
	References	350



Part IV People and Seascapes 365

- 12 Advancing a Holistic Systems Approach in Applied Seascape Ecology 367
Simon J. Pittman, Chris A. Lepczyk, Lisa M. Wedding and Camille Parrain
 - 12.1 Introduction 367
 - 12.1.1 What can Landscape Ecology Offer? 369
 - 12.1.2 A Shift towards a more Holistic Systems Approach for Marine Stewardship 370
 - 12.2 People as Part of the Seascape 373
 - 12.3 How Holistic Systems Science can Help Seascape Ecology 375
 - 12.3.1 Properties of an Ecological Systems Approach 376
 - 12.3.2 The Rise of Whole-of-System Modelling 377
 - 12.4 Connecting Seascape Patterns to Human Health, Livelihoods and Wellbeing 379
 - 12.5 Conclusions and Future Research Priorities 381
 References 384
- 13 Human Ecology at Sea: Modelling and Mapping Human-Seascape Interactions 391
Steven Saul and Simon J. Pittman
 - 13.1 Introduction 391
 - 13.2 Seascape Ecology, Spatial Patterns and Scale 393
 - 13.2.1 Scale and Scaling 395
 - 13.3 Human Use Data Types and Geographical Information Systems 396
 - 13.3.1 Mapping Human Behaviour across the Seascape 397
 - 13.3.1.1 Remote Sensing 398
 - 13.3.1.2 Participatory Mapping and Spatial Analysis 401
 - 13.3.1.3 Social Sensing 402
 - 13.3.1.4 Mapping Ecosystem Services 402
 - 13.4 Modelling Human-Seascape Interactions with a Systems Approach 403
 - 13.4.1 Custom-built Statistical Models 405
 - 13.4.2 Predefined Statistical Routines 406
 - 13.4.3 Discrete Choice Models 407
 - 13.4.4 Simulation Modelling 408
 - 13.4.5 Agent-based Models 411
 - 13.4.6 Pattern-oriented Modelling 412
 - 13.5 Conclusions and Future Research Priorities 415
 References 418

14	Applying Landscape Ecology for the Design and Evaluation of Marine Protected Area Networks	429
	<i>Mary A. Young, Lisa M. Wedding and Mark H. Carr</i>	
14.1	Introduction	429
14.2	Applying Landscape Ecology Principles in the Marine Environment	430
14.3	Case Study: Applying Landscape Ecology to Evaluate a Network of MPAs in California	438
14.3.1	California Seafloor Data Sets	439
14.3.2	MPA Goal: Habitat Replication and Representativeness	441
14.3.3	MPA Goal: Protect Diversity and Abundance of Marine Life	442
14.3.4	MPA Goal: Reduce Movement across Boundaries	444
14.4	Synthesis	448
14.4.1	Mapping Technologies	448
14.4.2	MPA Effects on Biodiversity and Populations	449
14.4.3	Scale of Interaction between Species and Environment	449
14.4.4	Across-System Interactions	450
14.4.5	Population Connectivity	450
14.5	Conclusions and Future Research Priorities	451
	References	452
15	Seascape Economics: Valuing Ecosystem Services across the Seascape	465
	<i>Edward B. Barbier</i>	
15.1	Introduction	465
15.2	Habitat Connectivity and Seascape Goods and Services	467
15.3	Valuing Seascape Goods and Services	468
15.4	Example of a Mangrove-Coral Reef Seascape	472
15.5	Conclusions and Future Research Priorities	476
	References	478



Part V Epilogue 483

16	Landscape Ecologists' Perspectives on Seascape Ecology	485
	<i>Simon J. Pittman, John A. Wiens, Jianguo Wu and Dean L. Urban</i>	
16.1	Introduction	485
16.2	From Landscapes to Seascapes (and Back Again)	485
16.3	Seascape Ecology and Landscape Ecology: Distinct, Related and Synergistic	487
16.3.1	Landscape Ecology	488
16.3.2	Seascape Ecology	488
16.3.3	How can Landscape and Seascape Ecology Interact with Each Other?	489
16.4	Seascape Ecology	491
	References	493