

Contents

List of Contributors *xiii*

Preface *xv*

- 1 Ecoacoustics: A New Science 1**
Almo Farina and Stuart H. Gage
- 1.1 Ecoacoustics as a New Science 1
- 1.2 Characteristics of a Sound 1
- 1.3 Sound and its Importance 2
- 1.4 Ecoacoustics and Digital Sensors 3
- 1.5 Ecoacoustics Attributes 3
- 1.5.1 Population Census 4
- 1.5.2 Biological Diversity 4
- 1.5.3 Habitat Health 4
- 1.5.4 Time of Arrival/Departure of Migratory Species 4
- 1.5.5 Diurnal Change 5
- 1.5.6 Seasonal Change 5
- 1.5.7 Competition for Frequency 5
- 1.5.8 Trophic Interactions 5
- 1.5.9 Disturbance 5
- 1.5.10 Sounds of the Landscape and People 6
- 1.6 Ecoacoustics and Ecosystem Management 6
- 1.7 Quantification of a Sound 7
- 1.7.1 Species Identification 7
- 1.7.2 Acoustic Indices 7
- 1.8 Archiving Ecoacoustics Recordings 8
- 1.9 Ecological Forecasting 9
- References 9
- 2 The Duality of Sounds: Ambient and Communication 13**
Almo Farina and Stuart H. Gage
- 2.1 Introduction 13
- 2.2 Vegetation and Ecoacoustics 14
- 2.2.1 Vegetation Quality and Ecoacoustics 15
- 2.2.2 Soundscape Indices and Biodiversity 15

2.2.3	Applications of Remote Sensing of Vegetation and Ecoacoustics	16
2.3	Acoustic Resources, Umwelten, and Eco-fields	17
2.4	Sounds as Biological Codes	20
2.5	Sound as a Compass for Navigation	21
2.6	Geophonies from Sacred Sites – How to Incorporate Archeoacoustics into Ecoacoustics	22
2.6.1	The Characteristics of Geophonies	23
2.6.2	Geophonies and Sacred Sites	23
2.6.3	Human Versus Other Animals' Perception of Sound: The Role of Archeoacoustics	24
	References	24
3	The Role of Sound in Terrestrial Ecosystems: Three Case Examples from Michigan, USA	31
	<i>Stuart H. Gage and Almo Farina</i>	
3.1	Introduction	31
3.2	C1 Visualization of the Soundscape at Ted Black Woods, Okemos, Michigan during May 2016	31
3.2.1	C1 Background	31
3.2.2	C1 Objectives	32
3.2.3	C1 Methods	32
3.2.3.1	C1 Soundscape Metrics	33
3.2.3.2	C1 Weather Factors Affecting Sounds	33
3.2.4	C1 Results	33
3.2.4.1	C1 Patterns of Soundscape Power for Six Frequency Intervals	33
3.2.4.2	C1 Patterns of Soundscape Indices	37
3.2.4.3	C1 Wind Patterns During May 2016	37
3.2.4.4	C1 Rain Patterns During May 2016	37
3.2.4.5	C1 Spectrogram Patterns	41
3.2.5	C1 Discussion	42
3.3	C2 Implications for Climate Change – Detecting First Call of the Spring Peeper	44
3.3.1	C2 Background	44
3.3.2	C2 Methods	44
3.3.3	C2 Results	45
3.3.4	C2 Discussion	47
3.4	C3 Disturbance in Terrestrial Systems: Tree Harvest Impacts on the Soundscape	49
3.4.1	C3 Background	49
3.4.2	C3 Methods	51
3.4.3	C3 Results	52
3.4.3.1	C3 Changes in the Soundscape	52
3.4.3.2	C3 Statistical Influence of Forest Harvest	55
3.4.4	C3 Discussion	55
	References	59

4	The Role of Sound in the Aquatic Environment	61
	<i>Francesco Filiciotto and Giuseppa Buscaino</i>	
4.1	Overview on Underwater Sound Propagation	61
4.1.1	Sound Speed in the Sea	61
4.1.2	Transmission Loss	61
4.1.3	Deep and Shallow Sound Channel and Animal Communication	62
4.2	Sound Emissions and their Ecological Role in Marine Vertebrates and Invertebrates	63
4.2.1	Marine Mammals	63
4.2.2	Fish	64
4.2.3	Crustaceans	65
4.3	Impacts of Anthropogenic Noise in Aquatic Environments	67
4.3.1	Main Anthropogenic Sources of Noise in the Sea	67
4.3.2	The Effects of Anthropogenic Noise on Marine Organisms	68
4.3.2.1	Acoustic Masking and Damage to Hearing System of Marine Organisms	68
4.3.2.2	Biochemical Impacts and Stress Responses	69
4.3.2.3	Behavior Alterations	70
	References	71
5	The Acoustic Chorus and its Ecological Significance	81
	<i>Almo Farina and Maria Ceraulo</i>	
5.1	Introduction	81
5.2	Time of Chorus	82
5.3	The Chorus Hypothesis	86
5.4	Choruses in Birds	87
5.5	Choruses in Amphibians	87
5.6	Choruses in the Marine Environment	88
5.7	Conclusions and Discussion	89
	References	89
6	The Ecological Effects of Noise on Species and Communities	95
	<i>Almo Farina</i>	
6.1	Introduction	95
6.2	The Nature of Noise	96
6.3	Natural Sources of Noise	96
6.4	Anthropogenic Sources of Noise	97
6.5	Effects of Noise on the Animal World	97
6.6	How Animals Neutralize the Effect of Noise	100
6.6.1	Changing Amplitude	100
6.6.2	Changing Frequency	100
6.6.3	Changing Signal Redundancy	101
6.6.4	Changing Behavior	101
6.7	Noise in Marine and Freshwater Systems	101
6.8	Conclusions	102
	References	103

7	Biodiversity Assessment in Temperate Biomes using Ecoacoustics	109
	<i>Almo Farina and Nadia Pieretti</i>	
7.1	Introduction	109
7.2	Sound as Proxy for Biodiversity	110
7.3	Methods and Application of Ecoacoustics	111
7.4	Acoustic Communities as a Proxy for Biodiversity	113
7.5	Problems and Open Questions	114
7.6	Ecoacoustic Events: Concepts and Procedures	116
7.7	Conclusion	122
	References	122
8	Biodiversity Assessment in Tropical Biomes using Ecoacoustics: Linking Soundscape to Forest Structure in a Human-dominated Tropical Dry Forest in Southern Madagascar	129
	<i>Lyndsay Rankin and Anne C. Axel</i>	
8.1	Introduction	129
8.2	Methods	131
8.2.1	Study Area	131
8.2.2	Forest Sampling	132
8.2.3	Soundscape Survey	133
8.2.4	Acoustic Index	133
8.2.5	Mixed Model Analysis	134
8.3	Results	135
8.3.1	Acoustic Index by Season	135
8.3.2	Mixed Model Analyses	137
8.4	Discussion	137
	Acknowledgments	141
	References	142
9	Biodiversity Assessment and Environmental Monitoring in Freshwater and Marine Biomes using Ecoacoustics	145
	<i>Denise Risch and Susan E. Parks</i>	
9.1	Introduction	145
9.2	Freshwater Habitats	147
9.2.1	Rivers	147
9.2.1.1	Remote Monitoring of Biotic Signals in the Environment	147
9.2.1.2	Remote Monitoring of the Environment Using Sound in River Habitats	148
9.2.1.3	Anthropogenic Sources of Noise in River Systems	148
9.2.2	Lakes and Ponds	148
9.2.2.1	Remote Monitoring of Biotic Signals in the Environment	149
9.2.2.2	Remote Monitoring of the Environment Using Sound in Lakes and Ponds	149
9.2.2.3	Anthropogenic Sources of Noise in Lakes and Ponds	149
9.3	Marine Neritic Habitats	150
9.3.1	Estuaries and Coastal Habitats	150
9.3.1.1	Remote Monitoring of Biotic Signals in the Environment	150

9.3.1.2	Remote Monitoring of the Environment Using Sound in Estuarine and Coastal Habitats	150
9.3.1.3	Anthropogenic Sources of Noise in Estuarine and Coastal Habitats	152
9.3.2	Coral Reefs	152
9.3.2.1	Remote Monitoring of Biotic Signals in the Environment	152
9.3.2.2	Remote Monitoring of the Environment Using Sound in Coral Reef Environments	153
9.3.2.3	Anthropogenic Sources of Noise in Coral Reef Environments	153
9.4	Marine Oceanic Habitats	153
9.4.1	Open Ocean and Deep Sea Habitats	153
9.4.1.1	Remote Monitoring of Biotic Signals in the Environment	154
9.4.1.2	Remote Monitoring of the Environment Using Sound in the Open Ocean	154
9.4.1.3	Anthropogenic Sources of Noise in the Open Ocean	154
9.4.2	Polar Oceans	155
9.4.2.1	Remote Monitoring of Biotic Signals in the Environment	155
9.4.2.2	Remote Monitoring of the Environment with Sound in Polar Regions	155
9.4.2.3	Anthropogenic Sources of Noise in the Polar Regions	156
9.5	Summary and Future Directions	156
	References	158
10	Integrating Biophony into Biodiversity Measurement and Assessment	169
	<i>Brian Michael Napoletano</i>	
10.1	Introduction	169
10.1.1	Biodiversity and its Parameterization	170
10.2	Biological Information in the Soundscape	171
10.2.1	Physiology: Sound Production and Detection	174
10.2.2	Communication: Medium and Context	176
10.2.3	Coordination: Evolution of the Biophony	178
10.2.4	Adaptation: Mechanization of the Soundscape	180
10.3	Ecoacoustics in Biodiversity Assessment	182
10.3.1	Developing a Soundscape Monitoring Network	182
10.3.2	Acoustic Data Processing and Management	183
10.4	Conclusion	184
	References	185
11	Landscape Patterns and Soundscape Processes	193
	<i>Almo Farina and Susan Fuller</i>	
11.1	An Introduction to Landscape Ecology (Theories and Applications)	193
11.1.1	Patch Size, Shape, and Isolation	193
11.1.2	Patch-Matrix Context	194
11.2	Relationship Between Landscape Ecology and Soundscape Ecology: A Semantic Approach	195
11.2.1	The Contribution of Landscape Ecology to the Development of Ecoacoustics	196
11.2.2	Acoustic Heterogeneity in a Landscape Across Space and Time	197
11.3	Acoustic Community and Landscape Mosaics	199

11.4	Ecoacoustics in a Changing Landscape	202
11.5	Conclusion	203
	References	204
12	Connecting Soundscapes to Landscapes: Modeling the Spatial Distribution of Sound	211
	<i>Timothy C. Mullet</i>	
12.1	Introduction	211
12.2	Conceptualizing Soundscapes in Space and Time	211
12.3	Capturing Soundscapes in Space and Time	212
12.4	Sound Metrics and Interpreting Nature	213
12.5	A Soundscape Metric for Modeling	215
12.6	Discriminating the Components of a Soundscape	216
12.7	Generating a Predictive Soundscape Model	217
12.8	Conclusion	219
	Disclaimer	221
	References	221
13	Soil Acoustics	225
	<i>Marisol A. Quintanilla-Tornel</i>	
13.1	Introduction	225
13.2	Soil Insect Acoustics	226
13.3	Compost Activating Agent Acoustics	226
13.4	Soil Aggregate Slaking Acoustics	227
13.5	Conclusion	230
	References	231
14	Fundamentals of Soundscape Conservation	235
	<i>Gianni Pavan</i>	
14.1	Introduction	235
14.2	Nature Sounds in Science and Education	238
14.3	The Role of Sound Libraries	242
14.4	Noise Pollution, the Acoustic Habitat, and the Biology of Disturbance	243
14.5	Soundscapes, Nature Conservation, and Public Awareness	244
14.6	Marine Soundscapes	245
14.6.1	Ship Noise	246
14.7	Conclusion	251
14.7.1	Terrestrial Soundscapes	252
14.7.2	Marine and Aquatic Soundscapes	252
	Acknowledgment	252
	References	252
15	Urban Acoustics: Heartbeat of Lansing, Michigan, USA	259
	<i>Stuart H. Gage and Wooyeong Joo</i>	
15.1	Introduction	259
15.2	Objectives	260
15.3	Methods	261

15.3.1	Sampling Design	261
15.3.2	Recording at Sample Sites	262
15.3.3	Data Conversion	262
15.3.4	Data Processing	262
15.4	Results	264
15.4.1	The NDSI	264
15.4.2	The H, ADI, AEL, ACI, and BIO Indices	267
15.5	Discussion and Conclusions	267
	References	271
16	Analytical Methods in Ecoacoustics	273
	<i>Stuart H. Gage, Michael Towsey and Eric P. Kasten</i>	
16.1	Introduction	273
16.2	Components of an Acoustic Recording	275
16.3	Visualization of an Acoustic Recording	276
16.3.1	Frequency Analysis	276
16.3.2	Three-Dimensional Spectrogram	277
16.4	Processing Multiple Recordings	277
16.5	Analyzing Acoustic Time Series	279
16.6	Time Series of Acoustic Indices	281
16.7	Searching and Symbolic Methods	282
16.7.1	Searching a Recording for Anomalies	284
16.7.2	Symbolic Representations and Unsupervised Learning	285
16.8	Visualization and Navigation of Long-Duration Recordings	286
16.9	Spectrogram Pyramids	289
16.9.1	Diel Plots	289
16.10	New Approaches to Analysis	291
16.11	Web Platforms for the Visualization of Environmental Audio	291
	References	293
17	Ecoacoustics and its Expression through the Voice of the Arts: An Essay	297
	<i>David Monacchi and Bernie Krause</i>	
17.1	Introduction	297
17.2	Immersive Art as a Science Dissemination Tool	299
17.3	Examples of Ecoacoustic Works by Bernie Krause	302
17.4	Examples of Ecoacoustics Works by David Monacchi	306
17.4.1	Designing Temples for the Ear: The Ecoacoustic Theater	309
17.4.2	Soundscape Projection Ambisonics Control Engine (S.P.A.C.E.)	310
17.5	Conclusion	311
	References	311
18	Ecoacoustics Challenges	313
	<i>Stuart H. Gage and Almo Farina</i>	
18.1	Introduction	313
18.2	Philosophical Issues	313
18.3	Ecological Issues	314

18.4	Sensor Technology	315
18.5	Acoustic Computations and Modeling	316
18.6	Public Information	316
18.7	Monetary Issues	317
	References	317
	Index	321