

Contents

Contributors	xvii
Preface.....	xxiii
Chapter 1 General Introduction	1
1.1 What Are Intermittent Rivers and Ephemeral Streams (IRES)?.....	1
1.2 Causes of Flow Intermittence	6
1.3 Global Distribution and Areal Importance of IRES.....	7
1.4 Trends in a Context of Water Scarcity and Climate Change	8
1.5 Ecological Features of IRES.....	8
1.6 Legislation, Protection, Restoration, and Management of IRES.....	11
1.7 The Structure of This Book	13
Acknowledgments	16
References.....	16
Chapter 2.1 Geomorphology and Sediment Regimes of Intermittent Rivers and Ephemeral Streams.....	21
2.1.1 Introduction.....	21
Determinants of IRES Catchment Conditions	22
Geomorphological Zones in IRES.....	23
2.1.2 Upland Zone	26
2.1.3 Piedmont Zone.....	29
2.1.4 Lowland Zone	32
2.1.5 Floodout Zone.....	35
2.1.6 Distinctions in IRES Longitudinal Trends.....	39
2.1.7 Influence of Human Activities on IRES Morphology and Sediment Regimes	40
2.1.8 Diversity of IRES at a Global Scale	41
2.1.9 Synthesis and New Research Directions	43
Acknowledgments	44
References.....	44
Chapter 2.2 Flow Regimes in Intermittent Rivers and Ephemeral Streams	51
2.2.1 Introduction.....	51
2.2.2 Controls on the Natural Flow Regime of IRES	54
2.2.3 Methods to Characterize Flow Regimes of IRES.....	54
Wet/Dry Mapping	56
Imagery: From Satellites to Site Cameras	57
Field Loggers and Flow Surrogates.....	58

Hydrological Metrics	59
Modeling	62
2.2.4 Describing and Classifying Flow Regimes of IRES: Case Studies	63
2.2.5 Conclusions: Research Needs and Future Perspectives	70
Acknowledgments	73
References	74
Further Reading	78
Chapter 2.3 Hydrological Connectivity in Intermittent Rivers and Ephemeral Streams	79
2.3.1 Introduction	79
2.3.2 What Governs Hydrological Connectivity in IRES?	81
2.3.3 Hydrological Connectivity, Intermittence, and Surface Water Drying and Rewetting in IRES	83
2.3.4 Longitudinal Hydrological Connectivity in IRES	85
2.3.5 Lateral Hydrological Connectivity in IRES	89
2.3.6 Vertical Hydrological Connectivity in IRES	92
2.3.7 A Preliminary Conceptual Framework for Exploring Intermittence, Connectivity, and Interacting Hydrological Dimensions in IRES	98
2.3.8 Conclusions	102
Acknowledgments	103
References	103
Further Reading	108
Chapter 3.1 Water Physicochemistry in Intermittent Rivers and Ephemeral Streams	109
3.1.1 Introduction	109
3.1.2 Spatial Variability of Physicochemistry in IRES	111
The Longitudinal Dimension	111
The Vertical Dimension	114
The Lateral Dimension	116
3.1.3 Temporal Variability of Water Physicochemistry in IRES	116
Daily Variability	118
Seasonal Variability	119
Interannual Variability in Physicochemistry: Some Factors Involved	123
Temporal Variability at Longer Scales: IRES in the Context of Global Change	124
3.1.4 Changes in Water Physicochemistry During Drying and Rewetting	125
Physicochemistry in Remnant Pools	126
Physicochemistry During Complete Drying and the Rewetting Front	127
3.1.5 Conclusions	129
References	129
Further Reading	134

Chapter 3.2	Nutrient and Organic Matter Dynamics in Intermittent Rivers and Ephemeral Streams	135
3.2.1	The 'Biogeochemical Heartbeat' of IRES	135
3.2.2	Nutrient and OM Dynamics Across Hydrological Phases in IRES	137
	Contraction	137
	Fragmentation	139
	Drying (Desiccation)	142
	Expansion	146
3.2.3	Knowledge Gaps and Research Opportunities	150
	References	153
Chapter 4.1	The Biota of Intermittent Rivers and Ephemeral Streams: Prokaryotes, Fungi, and Protozoans	161
4.1.1	Role and Relevance of Microbes in IRES	161
4.1.2	Diversity of Prokaryotes in IRES	164
	Factors Controlling Prokaryotic Communities in IRES	164
	Prokaryotic Diversity in IRES vs Perennial Rivers and Streams	166
4.1.3	Diversity of Fungi in IRES	167
	Factors Controlling Fungal Communities in IRES	167
	Fungal Diversity in IRES vs Perennial Rivers and Streams	170
4.1.4	Diversity of Protozoans in IRES	171
	Factors Controlling Protozoan Communities in IRES	171
	Protozoan Diversity in IRES vs. Perennial Rivers and Streams	173
4.1.5	Resistance and Resilience of Microbes in IRES	173
	Refugial Habitats	174
	Microbial Life Strategies	176
4.1.6	Microbial Diversity and Ecosystem Functioning in IRES	177
	Roles of Microbes in River Ecosystem Functioning	177
	Microbial Functioning in IRES and Links With Microbial Community Structure	178
4.1.7	Future Challenges	181
	References	181
Chapter 4.2	The Biota of Intermittent Rivers and Ephemeral Streams: Algae and Vascular Plants	189
4.2.1	Introduction: Primary Producers in IRES	189
4.2.2	Microbial Primary Producers in IRES: Cyanobacteria and Algae	190
	Morphological and Physiological Adaptations to Drying	191
	Algal-Derived Stream Metabolism in IRES	192
	Latitudinal Variation in Algal Community Composition	196
4.2.3	Vascular Aquatic Plants	198
	Vascular Macrophytes in IRES	199
	Vascular Plant Adaptations to Drying	199
	Implications of Drying for Vascular Plant Species Richness	204

4.2.4	Vascular Riparian Plants	204
	Riparian Vegetation Along IRES in Different Ecoregions.....	204
	Riparian Plant Adaptations in IRES	206
	Reproductive Trait Adaptations and Trade-Offs	207
	Landscape Biodiversity Patterns.....	208
4.2.5	Conservation and Management Issues of Primary Producers in IRES.....	209
	References.....	210
	Further Reading	216
Chapter 4.3	The Biota of Intermittent Rivers and Ephemeral Streams: Aquatic Invertebrates	217
4.3.1	Introduction.....	217
4.3.2	IRES as Habitats for Aquatic Invertebrates	218
4.3.3	Taxonomic Diversity of IRES Invertebrate Communities	218
	Temporal Variability in Taxonomic Diversity.....	219
	Spatial Variability in Taxonomic Diversity	224
	Phylogenetic Diversity.....	225
4.3.4	Functional Diversity of IRES Invertebrate Communities.....	225
4.3.5	Invertebrate Adaptations to Flow Intermittence.....	226
	Refuge Use Promotes Persistence in IRES.....	227
	Life Cycle Adaptations and Refuge Use Interact to Promote Survival	230
	Adaptations to IRES Are Trade-Offs That Also Influence Other Aspects of Survival.....	231
4.3.6	Threats to IRES Invertebrate Communities	231
4.3.7	Managing IRES to Promote Aquatic Invertebrate Biodiversity.....	235
4.3.8	Conclusions and Future Research Priorities	236
	References.....	237
Chapter 4.4	The Biota of Intermittent Rivers and Ephemeral Streams: Terrestrial and Semiaquatic Invertebrates	245
4.4.1	Introduction.....	245
4.4.2	Habitat Requirements of IRES Invertebrates.....	249
4.4.3	Taxonomic Diversity of TSAI Communities	253
4.4.4	Functional Diversity of TSAI Communities.....	257
4.4.5	Adaptations of TSAI to Flow Intermittence	258
4.4.6	Threats to the TSAI Communities of IRES	260
4.4.7	Managing IRES to Preserve TSAI Diversity and Their Ecological Functions.....	261
4.4.8	Knowledge Gaps and Research Needs	265
4.4.9	Conclusions.....	266
	References.....	266

Chapter 4.5 The Biota of Intermittent Rivers and Ephemeral Streams: Fishes	273
4.5.1 Introduction	273
4.5.2 The Fish Fauna of IRES	274
African IRES and Their Fishes	274
Australian IRES and Their Fishes	276
North American IRES and Their Fishes	277
IRES of Mediterranean Europe and Their Fishes	278
4.5.3 Why Do Fish Live in IRES?	279
4.5.4 How Do Fish Survive in IRES?	281
4.5.5 Threats to Fishes in Intermittent Rivers	286
Drought and Climate Change	288
Water Extraction, River Regulation, and Fragmentation of Habitat	288
Alien Species	289
4.5.6 Conservation Priorities for Fish in IRES	290
4.5.7 Conclusions	292
References	294
Chapter 4.6 The Biota of Intermittent and Ephemeral Rivers: Amphibians, Reptiles, Birds, and Mammals	299
4.6.1 Introduction	299
4.6.2 Importance of IRES for Amphibians, Reptiles, Birds, and Mammals	300
Water and Food Resources	301
Breeding and Nesting Sites	302
Aquatic and Terrestrial Movement Corridors	303
Migration Stopovers and Resting and Shelter Areas	303
4.6.3 Ecological Roles of Wildlife in IRES	304
Consumers, Prey, and Seed Dispersal Agents	304
Landscape Engineers	305
Nutrient Cycling	307
4.6.4 Flow Intermittence Effects on Wildlife	307
Amphibians	307
Reptiles	308
Birds	308
Mammals	308
4.6.5 Wildlife Adaptations to Cope With Flow Intermittence	309
Morphological Adaptations	309
Physiological Adaptation	310
Behavioral Adaptations	310

4.6.6	Vulnerability, Conservation, and Management of Wildlife in IRES	311
	Flow Alteration and Habitat Degradation	311
	Water Pollution	312
	Spread of Invasive Species and Diseases	312
	Climate Change	313
	Recommendations for Conservation and Management in the Context of Global Change	313
4.6.7	Conclusions	314
	Acknowledgments	314
	References	315

Chapter 4.7 Food Webs and Trophic Interactions in Intermittent Rivers and Ephemeral Streams 323

4.7.1	Introduction	323
4.7.2	The Base of IRES Food Webs	326
4.7.3	Consumer-Resource Dynamics in IRES	328
4.7.4	Multidimensional Interactions Within IRES	331
	Longitudinal Interactions	331
	Lateral Interactions	333
	Vertical Interactions	334
4.7.5	Effects of Regional Differences on Food Webs in IRES	336
4.7.6	Structure of IRES Food Webs	338
4.7.7	Trophic Interactions in IRES in the Future	341
	References	342
	Further Reading	347

Chapter 4.8 Resistance, Resilience, and Community Recovery in Intermittent Rivers and Ephemeral Streams 349

4.8.1	Introduction: Challenges of Persisting in IRES	349
4.8.2	Resistance Mechanisms of Aquatic Taxa	353
	Remnant Pools	353
	Hyporheic Zone	355
	Desiccation-Resistant Stages	355
4.8.3	Resilience Mechanisms of Aquatic Taxa	357
	Dispersal via Drift	357
	Dispersal via Crawling and Swimming	357
	Aerial Dispersal	358
	Environmental Cues That Trigger Dispersal	358
4.8.4	Aquatic Community Recovery Patterns Following Flow Resumption	358
4.8.5	Dynamics of Terrestrial Communities Inhabiting Dry Streambeds	361

4.8.6 Genetic Implications of Different Modes of Resistance and Resilience	364
4.8.7 Human Impacts Impair Resistance and Resilience Processes	366
Hydrological Alterations	366
Physical Alterations	368
4.8.8 Knowledge Gaps and Future Research Directions	369
References	370
Further Reading	376

Chapter 4.9 Habitat Fragmentation and Metapopulation, Metacommunity, and Metaecosystem Dynamics in Intermittent Rivers and Ephemeral Streams 377

4.9.1 Introduction	377
4.9.2 Connectivity, Fluxes, and Dispersal in River Networks Fragmented by Flow Intermittence	379
IRES as Dynamic and Shifting Habitat Mosaics	379
Flow Intermittence and Connectivity	380
Flow Intermittence and Dispersal	380
4.9.3 Metapopulation Dynamics in IRES	381
Conceptual Background of Metapopulation Ideas	381
Metapopulations in IRES: Why So Few Models?	382
How to Deal With Dispersal in Dendritic Networks?	382
How to Deal With Dynamic and Shifting Habitat Mosaics?	383
Existing Metapopulation Studies in IRES	383
Where to Go From Here?	384
4.9.4 Metacommunity Dynamics in IRES	385
Conceptual Background of Metacommunity Ideas	385
How to Study Metacommunities in IRES?	385
Species Turnover and Nestedness in IRES Metacommunities	386
Metacommunities in IRES	388
Biodiversity Partitioning in IRES	390
Where to Go From Here?	392
4.9.5 Metaecosystem Dynamics in IRES	392
Conceptual Background of Metaecosystem Ideas	392
IRES as Metaecosystems: Insights From Organic Matter Dynamics	392
Where to Go From Here?	397
4.9.6 Research and Management Perspectives	397
4.9.7 Conclusions	398
References	398
Further Reading	403

Chapter 4.10 Genetic, Evolutionary, and Biogeographical Processes in Intermittent Rivers and Ephemeral Streams	405
4.10.1 Introduction	405
4.10.2 Microevolutionary Ecology Processes in IRES	407
Characteristic Traits to Cope With Life in IRES	407
Potential Trade-Offs in IRES: To Stay or to Leave?	412
Genetic Structure in IRES	412
4.10.3 Macroevolutionary Ecology Processes in IRES	415
4.10.4 Evolutionary Processes at the Ecosystem Level in IRES	418
Biological Traits in IRES and Their Relation to Ecosystem Functions	418
Biodiversity-Ecosystem Functions Relationships in IRES	418
Recurrent Ecological Succession in IRES as a Framework for Fast Evolution	420
4.10.5 Global Biogeographical and Macroecological Patterns of Aquatic Organisms in IRES	422
Local and Regional Factors Determining Diversity in IRES	422
Speciation, Extinction, and Immigration in IRES	424
Global Trait Patterns in IRES	425
4.10.6 IRES Are Ideal Settings for the Study of Ecology and Evolution: Conclusions and Future Research	426
References	427
Further Reading	431
Chapter 5.1 Anthropogenic Threats to Intermittent Rivers and Ephemeral Streams	433
5.1.1 Introduction: The Main Threats to IRES	433
5.1.2 Hydrological Alterations in IRES	435
Hydrological Alterations Associated With Anthropogenic Water Withdrawals	437
Hydrological Alterations That Induce Perennial Flow in Natural IRES	439
5.1.3 Physical and Chemical Alterations in IRES	440
Exploitation of IRES and Dry Riverbeds by Humans	440
IRES and Water Quality Degradation	441
5.1.4 Biological Alterations in IRES: Invasive Species	442
5.1.5 Cascading Effects of Hydrological, Physical, Chemical, and Biological Alterations in IRES on Adjacent Ecosystems	444
5.1.6 The Challenge of Assessing the Biological and Ecological Condition of IRES	446
5.1.7 Conclusions	448
Acknowledgments	448
References	448

Chapter 5.2 Ecosystem Services, Values, and Societal Perceptions of Intermittent Rivers and Ephemeral Streams	455
5.2.1 Introduction	455
5.2.2 What Ecosystem Services are Provided by IRES?	457
5.2.3 Valuing the ES of IRES	463
5.2.4 Societal Perceptions of IRES	469
5.2.5 Conclusions and Prognosis	471
Acknowledgments	472
References	472
* Further Reading	476
Chapter 5.3 Governance, Legislation, and Protection of Intermittent Rivers and Ephemeral Streams	477
5.3.1 Introduction	477
5.3.2 Brief History of Water Law Around the World	479
5.3.3 IRES Recognition in Water and Environmental Law	480
International Treaties: The Ramsar Convention	480
United States	481
European Union	487
Latin America and the Caribbean	493
Australia and New Zealand	496
Canada	498
South Africa	498
India	499
Israel and Palestine	499
5.3.4 Flow Intermittence Complicating the Governance of Water Use and Environmental Protection	500
5.3.5 A Way Forward for Sustainable Governance, Legislation, and Protection of IRES	502
5.3.6 Conclusions	503
Acknowledgments	504
References	504
Further Reading	507
Chapter 5.4 Restoration Ecology of Intermittent Rivers and Ephemeral Streams	509
5.4.1 Introduction	509
5.4.2 IRES and Their Catchments	511
5.4.3 Stream Restoration Background	512
5.4.4 Degradation and Restoration in a Catchment Context	515
5.4.5 Hydrological Impacts and Their Restoration	517

Altered Flooding Regimes	517
Loss of Flows	517
Increased Periods of Zero Flows	518
Antidrought	519
5.4.6 Riparian Zone Degradation and Restoration	519
5.4.7 Restoration of Instream Habitat and Refuges	523
5.4.8 Restoring Refuges and Colonization Pathways	523
5.4.9 Measuring Restoration Trajectory	524
5.4.10 Things to Consider for Now and for the Future	525
5.4.11 Conclusions	526
Acknowledgments	526
References	526
Further Reading	533
 Chapter 5.5 Strategic Adaptive Management (SAM) of Intermittent Rivers and Ephemeral Streams	 535
5.5.1 Introduction	535
5.5.2 The Management Challenge	536
Ecological Context	536
Social Context	537
5.5.3 Strategic Adaptive Management (SAM)	538
Definition	538
Framework	538
Making It Work	542
5.5.4 Case Studies—Status, Successes, Challenges, and the Future	542
Crocodile River, Kruger National Park (South Africa)	542
Tankwa Karoo National Park (South Africa)	547
Edward-Wakool River System—Tuppal Creek (Australia)	549
Macquarie Marshes (Australia)	550
5.5.5 Making It Work—A Shared Journey	552
5.5.6 Global Applications	556
5.5.7 Conclusions	557
Acknowledgments	557
References	557
Further Reading	562

Chapter 6	Conclusions: Recent Advances and Future Prospects in the Ecology and Management of Intermittent Rivers and Ephemeral Streams	563
6.1	Introduction	563
6.2	Fourteen Themes in the Ecology and Management of IRES	564
6.3	Remaining Gaps in Our Knowledge and Understanding of the Ecology and Management of IRES	574
	Methodological Gaps and Opportunities	574
	Geographical and Disciplinary Gaps and Opportunities	575
	Conceptual Gaps and Opportunities	580
6.4	Conclusions	581
	Acknowledgments	582
	References	582
Index		585