Central European Stream Ecosystems

The Long Term Study of the Breitenbach

Edited by Rüdiger Wagner, Jürgen Marxsen, Peter Zwick, and Eileen J. Cox



Edited by Rüdiger Wagner, Jürgen Marxsen, Peter Zwick, and Eileen J. Cox

Central European Stream Ecosystems

Related Titles

Moss, B.

Ecology of Fresh Waters A View for the Twenty-First Century 2010 ISBN: 978-1-4051-1332-8

Maltby, E., Barker, T. (eds.)

The Wetlands Handbook

2009 ISBN: 978-0-632-05255-4

Rice, S., Roy, A., Rhoads, B. (eds.)

River Confluences, Tributaries and the Fluvial Network

2008 ISBN: 978-0-470-02672-4 Edited by Rüdiger Wagner, Jürgen Marxsen, Peter Zwick, and Eileen J. Cox

Central European Stream Ecosystems

The Long Term Study of the Breitenbach

With contributions from Georg Becker, Heino Christl, Thomas G. Horvath, Reimo Lieske, Michael Obach, Joachim Reidelbach, and Hans-Heinrich Schmidt

WILEY-BLACKWELL

The Editors

Prof. Dr. Rüdiger Wagner

University of Kassel FB 10 Natural Sciences - Biology Heinrich-Plett-Str. 40 34132 Kassel Germany

Dr. Jürgen Marxsen

Justus Liebig University Department of Animal Ecology Heinrich-Buff-Ring 26-32 35392 Giessen Germany

Prof. Dr. Peter Zwick

Schwarzer Stock 9 36110 Schlitz Germany

Dr. Eileen J. Cox

Natural History Museum Department of Botany Cromwell Road London SW7 5BD United Kingdom

Cover

The cover picture shows a view (looking upstream direction) into the Breitenbach valley during spring, with the first greenhouse constructed over the stream for collecting emerging insects in 1969 in the background (photo: Jürgen Marxsen). The simplified scheme of carbon flow was designed after Figure 6.2 from this book. The photo of the Trichopteran species *Chaetopteryx villosa* was kindly provided by Dipl.-Biol. Brigitta Eiseler.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty can be created or extended by sales representatives or written sales materials. The Advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Card No.: applied for

British Library Cataloguing-in-Publication Data A catalogue record for this book is available from the British Library.

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.d-nb.de>.

© 2011 Wiley-VCH Verlag & Co. KGaA, Boschstr. 12, 69469 Weinheim, Germany

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical, and Medical business with Blackwell Publishing.

All rights reserved (including those of translation into other languages). No part of this book may be reproduced in any form – by photoprinting, microfilm, or any other means – nor transmitted or translated into a machine language without written permission from the publishers. Registered names, trademarks, etc. used in this book, even when not specifically marked as such, are not to be considered unprotected by law.

Cover Design Adam-Design, Weinheim Typesetting Toppan Best-set Premedia Limited, Hong Kong Printing and Binding Fabulous Printers Pte Ltd, Singapore

Printed in Singapore Printed on acid-free paper

Print ISBN: 978-3-527-32952-6 ePDF ISBN: 978-3-527-63467-5 ePub ISBN: 978-3-527-63466-8 Mobi ISBN: 978-3-527-63468-2 oBook ISBN: 978-3-527-63465-1

Foreword

This is an astonishing book and a great achievement by the small band of scientists who have written it. The Max Planck Society's "Flußstation" (River Station) worked from 1951 to 2006 at Schlitz, in Hessen in central Germany, very largely on the ecology of a single small stream, The Breitenbach (in English "Wide Brook" - which it really is not!) This concentration of effort was partly because the larger River Fulda, of which the Breitenbach is a first order tributary, had become very polluted, and it offered a more "pristine" ecosystem for study. The program was initiated by two giants of early stream ecology, whose names may not now be well known to modern students, certainly non-German ones. Joachim Illies was the founder of the "river zonation" school of lotic ecologists and Karl Müller was the originator of the eponymous "Müller's colonization cycle". Their pioneering work was carried on by a small team of scientists (five at any one time) plus assistants, mainly under the leadership of Peter Zwick, and this book is a testament to their dedication, persistence, and skill. This book is a goldmine, a unique compendium of detailed information on a stream (crucially including the underlying data that will be made publicly accessible). I urge students of the next generation to exploit and pore over this material because quality and reliability (of taxonomy and methodology) shine through the pages; these were all very highly skilled aquatic ecologists working with the best equipment, and the results are the best.

۱v

Let me mention a few highlights from the more than 600 pages. The list of animals from this tiny stream contains more than 2000 species! There are 820 species of insects alone! This is an order of magnitude greater than the species list from "my own" Broadstone Stream (Hildrew, 2009), another well-known stream community and a system of a similar size. The Breitenbach is in a highly diverse area of central Europe (not a biotically impoverished island), is not acidified or excessively enriched, and almost every animal group has been studied by an expert at some time over the last 50 years. Emerging adult insects were also trapped and specifically identified continuously from 1969 to 2006, thus accumulating rare species. Indeed, the high quality of the taxonomy applied to this system is a real highlight of the research program. This also applies to the algal work, in which live diatoms were identified, greatly increasing one's confidence that the many species identified from the different microhabitats were active in the stream, and not merely allochthonous inputs. The lesson is that the less exhaustive studies that we routinely see must greatly underestimate total diversity because the sample size is small and because "difficult" groups are ignored. But what is the meaning of this diversity? Ecosystem processes in less diverse systems seem to proceed perfectly adequately. Does this indeed point to a high redundancy in stream ecosystems?

For those concerned with climate change, mean water temperature in the Breitenbach has increased only by about 0.85°C in 37 years (0.023°Cyear⁻¹), whereas air temperature has increased by 1.8°C in only 20 years (0.08°Cyear⁻¹). Warming in this spring-fed system has thus been rather slight and, perhaps not surprisingly, evidence for biological responses is muted. The date of emergence has not changed significantly for most species, though many show some indication of earlier (and a few of later) emergence. Exhaustive chemical analyses of the water have been undertaken. Not surprisingly, nutrient concentrations are low, but alkalinity and acid-neutralizing capacity showed some sign of decline over the whole record (in an area where acid depositions have been quite serious though decreasing over the last 20 years or so). The stream is circumneutral, however, and is not acidified (pH 6.5–7.8).

The macrofaunal community has also been remarkably persistent, the dominant species having remained almost unchanged over 37 years, though numerical fluctuations have been large. Year to year fluctuations in stream discharge, through a variety of direct and indirect effects but mainly via determining habitat availability for the guilds of scrapers and filterers, seem proximally associated with these shifts in density. Very large populations of trichopteran grazers, such as *Agapetus fuscipes* and *Tinodes rostocki*, dominate the epilithic community when clean stone surfaces are available, and the former appears to regulate algal biomass via grazing and to compete intraspecifically for food.

The microbiology (particularly bacteriology, there is less information on the fungi) of the system has been exceptionally well described, as have organic budgets. There have been no particular surprises here, but lotic systems for which there are reliable and complete measurements of flows in the microbial loop are few, and this is an absolutely prime example. Bacteria are responsible for 78% of heterotrophic respiration and 59% of total system respiration, accounting for 36% of heterotrophic biomass and most (71%) of heterotrophic production. About 50% of bacterial production enters the higher food web, 35% via protozoa, and 15% by direct consumption via the macrofauna. About 10% of carbon assimilated by the macrofauna is bacterial, the latter getting most carbon direct from dead organic matter. Bacterial production is similar to that of phototrophs, even in this well-lit, open stream, at about 0.2 kg m⁻² year⁻¹. The system is dominated by allochthonous inputs, with about 1.02 kg m⁻²year⁻¹ of dissolved organic matter and 0.42 kg m⁻²year⁻¹ of particulate organic matter. The chemical nature of dissolved organic matter has been unusually well characterized, as has the nature of flowing and interstitial water. Work on the microbiology and organic carbon budget of the Breitenbach has been of an international standard and deserves much more recognition. Overall, the carbon budget of the Breitenbach for the period 1973-1998 balances, with total inputs of 1.88kg m⁻²year⁻¹ and outputs of 1.84kg m⁻²year⁻¹, with allochthonous inputs about three times that from autochthonous sources. None of this is particularly surprising, a small, headwater stream dominated by allochthonous inputs and bacteria being major metabolic drivers of the system, but the quality of the measurements underlying these figures is first rate.

As it was at its completion, the "Breitenbach project" was in some senses science from an earlier age, frankly largely descriptive and driven by an intimate knowledge of natural history and conventional taxonomy. This is at the same time its strength, and it has hitherto been very much underestimated as a "model ecosystem", and its weakness. Along with the solidity, reliability, and sheer quantity of the data, there have been disappointments and blemishes, which are partly scientific and partly, I suspect, due to the dynamics of the team. It was a frustration that the measurement of insect emergence, motivated initially by the notion that it would lead to a "short-hand" measurement of secondary production, did not in the end do so. The book spends some time detailing the problems of measuring emergence quantitatively. Surprisingly also, the measurements of emergence were not accompanied by a sufficient campaign to measure benthic density. I feel that the authors are too pessimistic in their dismissal of more direct ways of measuring secondary production. There is almost nothing about vertebrates in this book, and they are more or less dismissed as having "no role". This is surely an overstatement; there is a population of brown trout in the lower reaches of the Breitenbach, yet it has not been characterized quantitatively. Work on the fish would surely have led to an appreciation of links between the aquatic food web and the riparian system, via subsidies to fish production from terrestrial resources. The team also had unrivalled measures of potential reverse subsidies, of the stream to riparian predators via insect emergence, long before they were appreciated elsewhere.

Finally, of course, we have to mention the problem of replication. This is one system, though some attempt is made to compare it with one or two other streams in the area. This is always a problem when producing a model ecosystem (though the book itself never describes the Breitenbach as a model). These are essential in ecology but only of use when they can be compared with others that differ in well-characterized ways. With hindsight, it would surely have been wise to set up a network of systems where comparisons with the "jewel in the Crown", the Breitenbach itself, would have been possible, thus increasing the generality of the inferences drawn.

I want to end my foreword by looking forward-since I really hope this is not a dead end for research on this system. As I said at the outset, the data are there and offer wonderful opportunities for the imaginative and curious. But if I were standing at the threshold of a new program, with all the battery of techniques in ecology now available, the Breitenbach and its heritage would be a wonderful place to start. I have no remit to develop a new program, but an obvious start would be to characterize the diversity using molecular methods (this was begun with the bacteria) and to place this stream within a meta-community of its neighbors. I would look further at groundwater-stream linkages-for groundwater is the new frontier for freshwater ecologists-and particularly look at the possibility of subsidies to the food web from chemoautotrophic production (via methane, for instance).

VIII Foreword

My third line would be to develop a food web for the Breitenbach, embedded within the terrestrial system, using stable isotopes, measurements of fatty acids markers, and the rest. This book should be a new beginning, not an epitaph.

Alan Hildrew

Reference

Hildrew, A.G. (2009) Sustained research on stream communities: a model system and the comparative approach. *Advances in Ecological Research*, **41**, 175–312.

Contents

	Foreword V
	List of Contributors XIX
	Acknowledgments XXI
1	Introduction 1
	Peter Zwick
1.1	History of the Limnologische Flussstation Schlitz 1
2	The Breitenbach and Its Catchment 5
	Jürgen Marxsen, Rüdiger Wagner, and Hans-Heinrich Schmidt
2.1	Study Area 5
2.2	The Stream and the Catchment 7
2.3	Sampling Sites 18
3	Environmental Characteristics 21
	Hans-Heinrich Schmidt
3.1	Climate and Weather 21
3.1.1	Global Irradiance 21
3.1.1.1	Local Effects of Irradiance in the Catchment 24
3.1.2	Precipitation 24
3.1.3	Wind 27
3.1.4	Air Temperature 32
3.1.5	Discharge 34
3.1.5.1	Base Flow and Base Flow Index (BFI) 36
3.1.5.2	Falling Limb 38
3.1.5.3	Rising Limb 39
3.1.5.4	Flow Duration Curve 39
3.1.5.5	High Water 41
3.1.5.6	Bank-Full 43
3.1.5.7	Water Saturation of the Valley 44
3.1.5.8	Input Average 44
3.1.5.9	Low Water 44
3.2	Attempt to Define Substratum Dynamics 44

іх

- Contents
 - 3.2.1 Cross-Section Measurements 46
 - 3.2.2 Wet Stream Area 46
 - 3.2.3 Water Temperature 47
 - 3.2.3.1 Water Temperature in the Sediment 47
 - 3.2.3.2 Water Temperature in the Stream 47
 - 3.3 Chemistry 56
 - 3.3.1 Buffering Capacity (ABC-Acid Binding Capacity) 57
 - 3.3.2 pH 59
 - 3.3.3 Oxygen 60
 - 3.3.4 Soluble Inorganic Elements 64
 - 3.3.4.1 Methods 64
 - 3.3.4.2 Nitrogen 64
 - 3.3.4.3 Phosphate 69
 - 3.3.4.4 Silicate 70
 - 3.3.4.5 Sulfate 71
 - 3.3.4.6 Chloride 71

4 Detrital Energy Sources 73

- 4.1 Organic Matter in Streams 73 Jürgen Marxsen
- 4.2 Particulate Organic Matter 74 Jürgen Marxsen and Rüdiger Wagner
- 4.2.1 Particulate Organic Matter in Streams 74
- 4.2.2 POM Inputs to the Breitenbach 75
- 4.2.2.1 Measuring Periods and Methods 75
- 4.2.2.2 Seasonal Distribution of CPOM Inputs 76
- 4.2.2.3 Amounts of CPOM Inputs in Various Years and Stream Sections 78
- 4.2.2.4 Composition of CPOM Inputs 81
- 4.2.2.5 Total Inputs of POM 82
- 4.2.3 Standing Stocks of POM in the Breitenbach 83
- 4.2.4 Outputs of POM from the Breitenbach 83
- 4.3 Dissolved Organic Matter 84 Jürgen Marxsen
- 4.3.1 Dissolved Organic Matter in Streams 84
- 4.3.2 Concentrations and Dynamics of Dissolved Organic Matter in the Breitenbach 84
- 4.3.3 Inputs and Outputs of Dissolved Organic Matter to and from the Breitenbach 89
- 4.3.4 Composition of Dissolved Organic Matter in the Breitenbach: Carbohydrates 91

5 Primary Producers 99

Eileen J. Cox, Jürgen Marxsen, and Thomas G. Horvath

- 5.1 Primary Producers in Streams 99
- 5.2 The Communities 100

X

- 5.2.1 Algae 100
- 5.2.1.1 Algal Assemblages in Streams 100
- 5.2.1.2 Spatial and Temporal Patterns of Diatom Occurrences in the Breitenbach *101*
- 5.2.1.3 Variation in Algal Biomass 108
- 5.2.1.4 Effects of Discharge on Benthic Diatom Assemblages 112
- 5.2.1.5 Microhabitats 115
- 5.2.1.6 Species Occurrences and Ecological Inferences 117
- 5.2.1.7 Impact of Grazers on Algal Assemblage and Biomass 122
- 5.2.1.8 General Conclusions from a Particular Ecosystem 122
- 5.2.2 Macrophytes 124
- 5.3 Primary Production 126

6 Bacteria and Fungi 131

Jürgen Marxsen

- 6.1 The Role of Bacteria and Fungi in Streams 131
- 6.2 The Communities 134
- 6.2.1 Bacterial Abundance and Biomass 134
- 6.2.1.1 Abundance in Different Habitats 134
- 6.2.1.2 Effects of Temperature and Discharge on Suspended Bacterial Abundance *139*
- 6.2.1.3 Bacterial Biomass 141
- 6.2.2 Bacterial Community Composition 142
- 6.2.2.1 Methodological Approaches 142
- 6.2.2.2 Cultivation 144
- 6.2.2.3 Fluorescence in situ Hybridization 145
- 6.2.2.4 Temperature Gradient Gel Electrophoresis 151
- 6.2.2.5 Sequence Analysis 154
- 6.2.2.6 Water versus Sediment Bacterial Communities 161
- 6.2.2.7 Community Composition: Conclusions 162
- 6.2.3 The Fungal Community 162
- 6.3 Microbial Metabolic Activity 163
- 6.3.1 Approaches to Microbial Metabolic Activity Measurements in the Breitenbach *163*
- 6.3.2 Extracellular Enzyme Activity 164
- 6.3.2.1 The Function of Extracellular Enzymes in Streams 164
- 6.3.2.2 Methodological Approach 166
- 6.3.2.3 Spatial Distribution 168
- 6.3.2.4 Activity of Different Enzymes 170
- 6.3.2.5 Environmental Controls and Regulation 175
- 6.3.2.6 The Molecular Biology Perspective 179
- 6.3.3 Bacterial Production 182
- 6.3.3.1 The Importance of Bacterial Carbon Production in Streams 182
- 6.3.3.2 Methodological Approach 183
- 6.3.3.3 Seasonal Fluctuation 184

XII Contents

6.3	.3.4	Small-Scale Variability and Particulate Organic Matter Content 188
6.3	.3.5	Influence of Temperature and Discharge 190
6.3	.3.6	Comparing BCP between Different Streams and Rivers 191
6.3	.3.7	Annual Bacterial Production and Respiration 193
6.3	.4	Fungal Production 194
7		The Fauna of the Breitenbach 195 Peter Zwick Georg Becker, Büdiger Wagner, and Joachim Beidelbach
7.1		Sampling Methods 196 Peter Zwick
7.1	.1	Collecting the Macrozoobenthos 196
7.1	.1.1	Study of Specimens 197
7.1	.1.2	Secondary Production 198
7.1	.1.3	Life Cycle Analyses 201
7.1	.1.4	Effect of an Insecticide Poisoning 201
7.1	.2	Collecting Insects in Emergence Traps 202
7.1	.2.1	Goals 202
7.1	.2.2	Types of Trap Used and Years of Operation 202
7.1	.2.3	Fundamentals of Emergence Trap Function 203
7.1	.2.4	Errors during Trap Operation 205
7.1	.2.5	Emergence Traps as Activity Traps and Terrestrial By-Catch 206
7.1	.2.6	Emergence Trap Collections and Estimates of Secondary Production 207
7.1	.2.7	Evaluation–Statistical Treatment of Data 208 Rüdiger Wagner
7.2		Protozoa: Ciliophora 209 Peter Zwick
7.3		Platyhelminthes and Annelida 211 Peter Zwick
7.3	.1	Platyhelminthes 211
7.3	.2	Annelida 212
7.4		Nematoda 212
		Peter Zwick and Heino Christl
7.5		Mollusca 214
		Peter Zwick
7.6		Arthropoda 216
		Peter Zwick
7.6	.1	Chelicerata 216
7.6	.2	Hydrachnidia 217
7.6	.3	Crustacea 218
7.6	.4	Insecta 219 Peter Zwick
7.6	.4.1	General and Minor Taxa 219
7.6	.4.2	Ephemeroptera 226
7.6	.4.3	Plecoptera 254

7.6.4.4	Coleoptera 309
7.6.4.5	Trichoptera 327
	Rüdiger Wagner
7.6.4.6	Aquatic Diptera 369
	Rüdiger Wagner
7.7	Chordata 404
	Peter Zwick
7.8	Ecophysiology, Behavior, and Life Cycles of Scrapers 405
	Georg Becker
7.8.1	Crowding Problems and Feeding Strategy of Tinodes rostocki
	(Trichoptera: Psychomyiidae), a Dominant Epilithic Caddisfly in the Middle and Lower Reaches of the Breitenbach 405
7.8.1.1	Larval Age Structure, Colonization of Natural Substrata, and
	Intraspecific Competition for Space in T. rostocki 405
7.8.1.2	Retreats of <i>T. rostocki</i> as a Substratum for Larval Food Resources 412
7.8.1.3	Feeding strategy of T. rostocki 419
7.8.2	Life Cycle and Ovipositing Adaptations of Agapetus fuscipes
	(Trichoptera, Glossosomatidae) to a First-Order Stream 421
7.8.2.1	Life Cycle of Glossosomatidae 421
7.8.2.2	Measurements of Pronotum Length, Larval Mass, and Case Length in
	A. fuscipes 422
7.8.2.3	Number of Larval Instars 423
7.8.2.4	Larval Mass and Case Length throughout the Ontogeny 424
7.8.2.5	Molt Increments 426
7.8.2.6	The Presence of Developmental Stages in the Breitenbach throughout
	the Year 427
7.8.2.7	Life Cycle Adaptation of <i>A. fuscipes</i> to a Small Uphill Stream 428
7.8.2.8	Ovipositing Behavior of Agapetus fuscipes 429
7.8.2.9	Egg Number and Egg Masses per Female 430
7.8.2.10	Distribution and Abundance of Egg Masses in the Breitenbach 430
7.8.2.11	Correlation between Egg Number and Cap Stone Size 431
7.8.2.12	Ovipositing Behavior of Glossosomatidae 432
7.8.3	Importance of Case Construction for Crawling Behavior and the
	Coexistence of Three Trichopteran Scrapers in the Upper Reach of the
	Breitenbach 432
7.8.3.1	Functions of Different Case Constructions for Trichopteran
	Species 432
7.8.3.2	Case Construction with Respect to Size, Shape, Composition, and
	Mass 433
7.8.3.3	Number and Size of Sand Grains 435
7.8.3.4	Use of Silk, Case Construction Costs, and Case: Larval Mass
	Quotient 436
7.8.3.5	Crawling Velocity of Larvae 436
7.8.3.6	Advantages of Different Case Constructions for Epilithic
	Scrapers 438

Contents

- Effect of Substratum Roughness on Larval Crawling Velocity 439 7.8.3.7
- 7.8.4 Interactions between Scrapers and Periphyton 442
- Introduction 442 7.8.4.1
- Comparison of the Dietary Composition of Epilithic Trichopteran 7.8.4.2 Species 445
- 7.8.4.3 Gut Content and Periphyton Analyses 446
- 7.8.4.4 Comparison between Species 446
- 7.8.4.5 Gut Content and Periphyton Composition throughout the Year 447
- Variability in Gut Content and Periphyton Composition along the 7.8.4.6 Stream 451
- 7.8.4.7 Primary Producers, Food Quality, and Resource Overlap 453
- 7.8.4.8 Interspecific Competition between Scrapers and Top-Down Control of Biofilms 455
- 7.8.4.9 Spatial and Temporal Development of Trichopteran and Ephemeropteran Grazers and Periphyton along the Breitenbach 459
- 7.8.4.10 Significance of Phototrophic Microorganisms for the Mortality, Growth, and Development of Trichopteran Scrapers 461
- 7.8.4.11 The Diurnal Foraging Behavior of A. fuscipes and D. annulatus 461
- 7.8.4.12 Food Choice in Laboratory Experiments 462
- 7.8.4.13 Response of Trichopteran Grazers to Biofilms of Diverse Quantity and Quality 467
- 7.8.4.14 Feeding Strategies and Ecological Segregation of Trichopteran Grazers in the Breitenbach 471
- 7.8.4.15 Conclusions 475
- 7.9 Effects of Water Temperature along the Breitenbach 476 Rüdiger Wagner
- 7.9.1 Water Temperature as an Important Variable for Explaining Body Size 476
- 7.9.2 Functional Feeding Groups 477
- 7.9.3 Experiments with Chaetopteryx villosa 478
- 7.9.3.1 Life Cycle and Adult Size at Different Stream Sites 478
- 7.9.3.2 Between-Sexes Size Difference 478
- 7.9.3.3 Field Experiment-Effects of Food and Temperature 480
- 7.9.3.4 Chaetopteryx villosa-Growth Models 481
- 7.9.4 Gammarus fossarum-Another Example 481
- 7.9.5 Water Temperature-A Limiting Resource 483
- Scrapers-Indication of Site-Specific Intra- and Interspecific 7.9.6 Competition Based on Emerged Adults 483
- 7.9.6.1 Caddisfly Scrapers – Size Differences along the Breitenbach 483
- 7.9.6.2 Within- and Between-Species Resource Limitation 484

8 Ecosystem Breitenbach 487

- 8.1 The Sandy Streambed Areas of the Breitenbach 487
 - Rüdiger Wagner, Jürgen Marxsen, and Hans-Heinrich Schmidt
- 8.1.1 Importance of Sediments in Streams 487

xiv I

Contents XV

- 8.1.2 The Breitenbach Streambed 488
- 8.1.3 Interstitial Water: Chemical Characteristics 490
- 8.1.4 Breitenbach Sandy Sediments as Habitat 495
- 8.2 Aquatic Insects Emerging over an Artificially Changed Stream Bottom 496 Rüdiger Wagner
- 8.2.1 The "Silted" Emergence Trap 498
- 8.2.2 Laboratory Experiments 499
- 8.2.3 Emerging Aquatic Insects 499
- 8.3 Discharge Patterns Largely Determine Species Abundance and Community Diversity 503
 Rüdiger Wagner and Hans-Heinrich Schmidt
- 8.3.1 Community and Variables Data Treatment 505
- 8.3.2 Environmental Variables 508
- 8.3.3 Community 512
- 8.3.4 Abundance and Discharge Pattern 514
- 8.3.5 Ordination 517
- 8.3.6 Discriminant Analysis 517
- 8.3.7 Community Diversity 519
- 8.3.8 Periods before and after 1990 522
- 8.3.9 The EPT Community of the Breitenbach and Environmental Variation 522
- 8.3.10 Multiple Stable Community States in Running Waters? 524
- 8.4 Eleven Years Emergence at Four Sites along the Breitenbach and the Effects of Discharge Patterns on the EPTD Community 526 Rüdiger Wagner and Hans-Heinrich Schmidt
- 8.4.1 Variables, Community, and Statistics 527
- 8.4.2 Environmental Variables 528
- 8.4.2.1 Precipitation 528
- 8.4.2.2 Discharge 528
- 8.4.2.3 Water Temperature 529
- 8.4.2.4 Air Temperature and Number of Rainy Days 529
- 8.4.3 Community 529
- 8.4.3.1 Distribution of Species along the Breitenbach 529
- 8.4.3.2 Species Affected by Discharge Pattern 531
- 8.4.3.3 Species with Simultaneous Spatial and Temporal Variability 534
- 8.4.3.4 Correspondence Analysis 534
- 8.4.3.5 Community Measures 537
- 8.4.3.6 Discriminant Analysis 539
- 8.4.4 Discussion 539
- 8.5 The Erlenbach–a Comparison with the Breitenbach 543 Rüdiger Wagner
- 8.5.1 Environmental Variables 545
- 8.5.1.1 Conductivity and pH 545
- 8.5.1.2 Discharge 545

XVI Contents

8.5.1.3	Air and Water Temperature 545
8.5.2	Community 547
8.5.3	Conclusion 553
8.6	Modeling Discharge and Insect Abundance with Artificial Neural
	Networks (ANNs) 554
	Michael Obach and Rüdiger Wagner
8.6.1	Precipitation–Discharge 555
8.6.2	Prognosis of Yearly Abundance of 17 EPT Species 557
8.6.3	Seasonal Effects of Variables on Species in Models 559
8.6.4	Effects of Discharge Parameters on Predictions of Monthly
	Abundances of Baetis rhodani 560
8.6.5	Predictions of Yearly Abundance Patterns 561
8.6.6	Abundance Predictions for the Caddisfly Apatania fimbriata at Four
	Sites along the Stream 562
8.6.7	General Aspects 563
8.7	Food Chains and Carbon Flow 564
	Jürgen Marxsen
8.7.1	The Organic Matter Budget of the Breitenbach 564
8.7.2	Bacteria in the Food Web System of the Breitenbach 567
8.8	Global Change and Timing of Insect Emergence at the
	Breitenbach 570
	Peter Zwick and Rüdiger Wagner
8.8.1	Introduction 570
8.8.2	Methods 572
8.8.2.1	Selection Criteria 572
8.8.2.2	Accuracy of Emergence Data and Possible Sources of Error 573
8.8.2.3	Shift in Emergence Dates 573
8.8.2.4	Emergence Dates and Temperature Regimes 573
8.8.3	Results 575
8.8.3.1	Shift in Emergence Time of Individual Ephemeroptera
	and Plecoptera Species 575
8.8.3.2	Shift in Emergence Time of Trichoptera Species 576
8.8.3.3	Emergence Dates and Thermal Regime 577
8.8.4	Discussion 578
9	Summary 585
	Georg Becker, Eileen I. Cox, Jürgen Marxsen, Hans-Heinrich Schmidt,
	Rüdiger Wagner, and Peter Zwick
9.1	Climate, Environment 585
9.1.1	Hydrological Chain 586
9.1.2	Thermal Chain 586
9.1.3	Water Chemistry 587
9.2	Detrital Energy Sources 587
9.3	Primary Producers 588
9.4	Bacteria 589

- 9.5 Organic Matter Balance and Carbon Flow 590
- 9.6 Fauna 591
- 9.6.1 The Dominant Pterygota 591
- 9.6.1.1 Ephemeroptera 592
- 9.6.1.2 Plecoptera 593
- 9.6.1.3 Trichoptera 594
- 9.6.1.4 Diptera 595
- 9.6.1.5 Coleoptera 595
- 9.6.2 Scrapers of the Breitenbach Community 596
- 9.7 Ecosystems 598
- 9.7.1 The Stream Bottom 598
- 9.7.2 Ordination 598
- 9.7.3 Modeling 599
- 9.7.4 Erlenbach 599
- 9.7.5 Global Change 600

References 601 Index 663

List of Contributors

Georg Becker

Universität of Cologne Cologne Biocenter Department of General Ecology Zülpicher Str. 47 b 50674 Köln Germany

Heino Christl

2 Poplar Way Harrogate HG1 5PR United Kingdom

Eileen J. Cox

The Natural History Museum Department of Botany Cromwell Road London SW7 5BD United Kingdom

Thomas G. Horvath

Director of Environmental Sciences Program State University New York College at Oneonta Oneonta, NY 13820 USA

Reimo Lieske

Im Alpenblick 10 8400 Winterthur Switzerland

Jürgen Marxsen

Justus Liebig University Department of Animal Ecology Heinrich-Buff-Ring 26-32 35392 Gießen Germany

Michael Obach

San Telmo 11-3° D. E-20750 Zumaia Spain

Joachim Reidelbach

Negelerstrase 53 72764 Reutlingen Germany

Hans-Heinrich Schmidt

Schlesische Str. 22 36110 Schlitz Germany

Rüdiger Wagner

University of Kassel FB 10 Natural Sciences – Biology Heinrich-Plett-Straße 40 34132 Kassel Germany

Peter Zwick Schwarzer Stock 9 36110 Schlitz Germany

Acknowledgments

The Max-Planck-Gesellschaft zur Förderung der Wissenschaften (MPG), its gremia and officers, and the directors and staff at the head office of the former Max-Planck-Institute of Limnology (Plön) are sincerely thanked for long-lasting funding and support of the Limnologische Fluss-Station Schlitz. We continued and developed a study initiated by the late Prof. J. Illies, who is gratefully remembered. After his sudden death, Prof. J. Overbeck (Plön) arranged for the continued existence of the Schlitz laboratory for which we are very grateful.

Visiting colleagues and students completing their theses at the Fluss-Station funded by the MPG, the Deutsche Forschungsgemeinschaft (DFG), or the Deutscher Akademischer Austauschdienst (DAAD) contributed to our study. They are too numerous to be listed here but their names appear in the text and the references of this book. We thank them all!

We are most grateful for the busy dedicated work of the team at the Fluss-Station Schlitz, everybody contributing in his specific capacity. We particularly thank our highly specialized and experienced technicians who participated directly in our everyday scientific work, some for decades:

Ingrid Aszmutat, Evelyn Etling, Dr. Beate Knöfel, Carla Kothe, Birgit Landvogt-Piesche, Carmen Möller, Agnes Palotay-Ries, Hannelore Quast-Fiebig, Gisela Stüber, Irene Tade, Elke Turba.

We are pleased to acknowledge taxonomic and ecological expertise, advice, information, and help from the following:

Dr. W. Barkemeyer (Flensburg), Dr. C. Becker (Aachen), R. Bellstedt (Gotha), Dr. R. Brinkmann (Schlesen), Dr. R. Gerecke (Tübingen), Dr. T. Gregor (Schlitz), Dr. P. Havelka (Karlsruhe), Dipl. Biol. M. Hecht (Herborn), Dr. R. Heiß (Frankfurt/Oder), H. Hergersberg (Hürtgenwald), Dr. H.-J. Krambeck (Plön), P.-W. Löhr (Mücke), Dr. P. Martin (Kiel), Dr. A. Piechocki, Łodz, Dr. A. Pont (Oxford), Dr. H. Reusch (Suhlendorf), W. Schacht (Schöngeißing), Dr. M. Spiess (München), Dr. U. Werneke (Kleve), Dr. K.-P. Witzel (Plön), Prof. F. Wojtas † (Łodz), Prof. Dr. T. Zatwarnicki (Wrocław), Dr. H. Zwick (Schlitz).

Schlitz, November 2010

The Editors

1 Introduction

Peter Zwick

1.1 History of the Limnologische Flussstation Schlitz

After World War II, Germany was divided into four occupation zones and free travel to neighboring countries was not possible. At that time, the Rivers Weser and Fulda formed the only major German river continuum that was accessible over its entire length. However, most of the second constituent tributary of the Weser, the River Werra in the Soviet Zone, was inaccessible. Therefore, the Fulda and Weser were the natural choice as study objects for a group of five biology students at the University of Göttingen who hoped to found an institute dedicated to stream limnology.

1

Martin Scheele, Joachim Illies, Wolfgang Schmitz, Karl Müller, and Ernst-Joseph Fittkau received local support from Prof. Demeter Beling and Dr. Adelaide Beling, German ichthyologists and microbiologists who had previously worked on the Dnjepr in Russia. Prof. August Thienemann, head of the famous Hydrobiologische Anstalt der Max-Planck-Gesellschaft (MPG) at Plön, soon became mentor and supporter of the enthusiastic group.

In 1949, the Belings and the five students sampled the River Fulda during what became a real expedition, under the adventurous conditions of post-war Germany. The group made contact with sport fishermen at Schlitz who expressed interest in, and eventually funded, an exhibition of freshwater fauna and flora entitled "*Das Leben unserer Heimatgewässer*" which was shown in the sportshall at Schlitz, in the autumn of 1949. The illustrious Otto Hartmann Graf von Schlitz, genannt von Görtz, visited and decided to provide the young students with a building to serve as a base for further studies of the River Fulda. He had his sculptor grandfather's former studio (first built in 1876) completely rebuilt and donated this plus some land and fishing rights to the MPG (Figure 1.1).

The opening ceremony of the Schlitz institute was held on 4 June 1951, in the presence of Count and Countess v. Görtz, Otto Hahn, President of the MPG, A. Thienemann from Plön, D. v. Denffer of the Justus-Liebig-Universität at Giessen, and many other guests. The choice of name, "*Limnologische Flussstation*"



Figure 1.1 The original building of the Limnologische Flussstation in 1951, and the name plate on its front wall.

(Figure 1.2)¹⁾, anticipated a change in scientific emphasis, which manifested itself years later when the long-established Hydrobiologische Anstalt at Plön became the Max-Planck-Institut (MPI) fuer Limnologie.

J. Illies held the single scientist's position at the Limnologische Flussstation Schlitz, but the salary was shared between the five founders until the other four found themselves different positions. Later, a second scientist's position was installed by the MPG. Since 1982, the payroll included 15 positions, of which five were scientists. The original building soon became too small. In 1959 the MPG added a large extension to the original building, and in 1969 Graf Otto Hartmann donated a former mill opposite the Flussstation (Figure 1.2). The MPG had the Hallenmühle transformed into a laboratory and office building. Great efforts were made to turn the millrace running through the building into a living stream laboratory. However, at that time the poor water quality of the River Schlitz precluded the maintenance of the stream fauna or any undisturbed experiments. Operating artificial streams with recirculating river water from a large reservoir was not a long-term viable alternative. Littoral filtrate of the river water was used for several years, mainly to run biofilm experiments. Eventually the room was dedicated to other technical equipment. In the main building, laboratory space was at a premium, until the MPG added a dedicated laboratory section in 1995.

The scientific activities of the Limnologische Flussstation are evidenced in the publication list, with contributions from staff members, visiting scientists, and, not least, graduate students working on master and doctoral theses. Research focused on a variety of subjects, with a change of emphasis over time.

In the first years, under Joachim Illies, the focus was on methodological studies, regional limnology and the regular sequence of characteristic biocoenoses along rivers. Much of this appeared in the *Jahresberichte* (later: *Berichte*) *der Limnologischen Flussstation Freudenthal*, the station's own periodical. The required taxonomic expert knowledge of stream fauna was largely developed by members of

See Fittkau (1992, 2001) for the history of the epithet "Freudenthal", further donors and additional offices operating on the Weser and so on for some limited time.

1.1 History of the Limnologische Flussstation Schlitz



Figure 1.2 The first extension building (1959; top left) is plastered and stands at a right angle to the original half-timbered building. The laboratory section added in 1995 extends

the old building longitudinally and copies its half-timbered style (bottom). The Hallenmühle (top right) stands across the road opposite the main building.

the Schlitz group themselves. Taxonomic expertise, an indispensible precondition for ecological studies, always remained a stronghold of the Flussstation.

Based on intimate knowledge of the Mölle stream in North-Rhine-Westfalia and of the River Fulda, J. Illies developed a concept of the biocenotic structure of streams (Illies, 1955), which he later extended as "*Versuch einer Allgemeinen Biozönotischen Gliederung der Fließgewässer*" (Illies, 1961). Only after organisms have been identified can their functions and roles in the ecosystem be analyzed. Illies' (1961) concept of river zonation therefore logically preceded the *River Continuum Concept* (Vannote *et al.*, 1980). The first describes the discontinuous distribution of biocoenoses along streams, the second the continuous change of functions along river continua. Although at first glance the concepts may seem contradictory, they are actually two sides of the same coin.

From 1957 onwards, J. Illies worked in the main institute at Plön while K. Müller led the Flussstation. Studies on organismal drift and fish biology then predominated. In 1965, the Flussstation became an outlier of the new Department of Microbial Ecology of J. Overbeck at Plön. J. Illies returned to Schlitz, as Prof. Overbeck's local representative, but because of these changes, several studies performed at Schlitz by K. Müller and collaborators were published elsewhere and are missing from our publication list (http://edoc.mpg.de/ins/22/col/399).

3

4 1 Introduction

For some years J. Illies and his students resumed their studies on the River Fulda before work at the Flussstation concentrated on two, first-order streams near Schlitz. Meanwhile the River Fulda had become heavily polluted while the small Breitenbach and Rohrwiesenbach were hardly disturbed and, because of their small size, more amenable to quantitative ecological studies. In both streams, Chordata play no role and invertebrates, especially insects and amphipods, dominate. J. Illies attempted to quantify the secondary production of stream insects by using emergence traps, initiating a series of emergence trap studies. Differences down the Breitenbach required several traps along its length, at the expense of work on the Rohrwiesenbach. A general survey of the Breitenbach fauna was performed and, for some time, amphipod ecology also received special attention (M.P.D. Meijering and students, compare the publication list of the Flussstation [http://edoc.mpg.de/ins/22/col/399]).

In June 1982, J. Illies suddenly died. As part of J. Overbeck's department the Limnologische Flussstation Schlitz was not closed and, in 1983, P. Zwick became head of the station and chose to continue work on the Breitenbach, to fully exploit previous work done there. When J. Overbeck retired, the MPG decided to continue the Schlitz station as an independent working group of the MPI of Limnology at Plön.

The various scientific activities of the LFS attracted visitors from all continents. A few spent sabbaticals in Schlitz, but most guests were funded by the MPG, the Deutsche Forschungsgemeinschaft (DFG) or the Deutscher Akademischer Austauschdienst (DAAD), staying between one month and two years. In a few cases, external funding from the DFG was available for longer periods. The Flussstation hosted several German and international limnological congresses, until limnological associations became too large to be accomodated within the small township of Schlitz. Among other congresses held at the LFS, were the First International Congress on Groundwater Ecology organized in conjunction with the Third International Symposium on Plecoptera (1977). The Deutsche Diatomologen Treffen was initiated in Schlitz in 1987, meeting annually since then and going on to become the Central European diatomists meeting. The Rhithron Ecology Group was also founded at Schlitz (1988).

Staff of the LFS were always actively involved in academic teaching. Graduate students from all parts of Germany came to work at Schlitz for their Diploma or Doctorate. Students of the LFS were treated as in-faculty students by the universities at Giessen, Kassel, Kiel, and Marburg. Cooperation with other universities was no exception.

The choice of a successor after the retirement of Prof. Overbeck indicated that the MPG was redirecting the institute at Plön, and it has now become the *Institute* of *Evolutionary Biology*. When the heads of the *Department of General Limnology* (Prof. W. Lampert), the *Working Group on Tropical Ecology* (Prof. W. Junk), and the LFS retired in short succession, from autumn 2006 onwards, limnology was discontinued in the main institute and the LFS was closed, after 56 years.

The present book summarizes some of the work done on the Breitenbach by the Schlitz River Station.

2 The Breitenbach and Its Catchment

Jürgen Marxsen, Rüdiger Wagner, and Hans-Heinrich Schmidt

2.1 Study Area

The Breitenbach is a small first-order stream, situated in eastern Hesse (Germany) between the Vogelsberg and Rhön mountains, approximately 4 km east of the town of Schlitz (10000 inhabitants) and 100 km northeast of Frankfurt am Main (Table 2.1, Figures 2.1 and 2.2). It was selected for a detailed ecosystem study not only because of its close vicinity to the Limnological River Station, but mainly because it is a typical Central European stream containing typical communities of organisms (Zwick, 1998a).

5

The catchment area is part of the "Fulda-Haune-Tafelland" (Fulda-Hauneplateau), which belongs to the larger "Osthessisches Bergland" (Eastern Hesse upland; Klausing, 1974). The Fulda-Haune-Tafelland is a large plateau (up to about 500 m a.s.l.) dominated by Middle Bunter Sandstone but occasionally perforated or superposed by basaltic rock. Pleistocene and Holocene debris, as well as eolian und fluvial sediments, are the predominant uppermost geologic layers (Kupfahl, 1964, 1965; Motzka, 1968a, b). Several streams and rivers carve valleys into the sandstone layers, down to about 200 m a.s.l. These valleys are mostly used for agriculture, sometimes including the gentler hillsides and their summits. About half of the region is covered by forests (Seibert, 1954; Bohn, 1996).

The Fulda-Haune-Tafelland experiences the typical temperate Central European climate. The winter temperatures are somewhat lower than in north-west, south-west and south Germany, but summer temperatures are similar to north-west Germany. However, the precipitation is lower and the typical westerly winds are less dominating (Schönhals, 1954). The annual average temperature of the region is between 7 and 8 °C, the mean values for January and July are between -1 to -2° and 16 to 17 °C, respectively (Deutscher Wetterdienst in der US-Zone, 1950). The maximum air temperatures remain below 0 °C for 20–40 days year⁻¹, the minimum temperatures fall below 0 °C for 80–120 days year⁻¹. Ten to 30 days year⁻¹ have temperatures above 25 °C. Annual precipitation in the region fluctuates between 550 mm and 750 mm. Ten to 15% of the precipitation falls as snow.

6 2 The Breitenbach and Its Catchment

Variable	Value
Latitude	50°39′N
Longitude	9°38′E
Catchment area	8.3 km ²
Stream length	6300 m
Stream length, main channel	4200 m
Stream bed area, main channel during base flow	3225 m
Average gradient	$0.033\mathrm{mm^{-1}}$
Mean annual water temperature	7.3 °C
Mean annual discharge above mouth at GT6	$261 s^{-1}$
Mean annual precipitation	63 cm
Mean annual air temperature	8.0°C

 Table 2.1
 Geographical and physical characteristics of the Breitenbach.



Figure 2.1 Network of major rivers in Germany and the position of the study area (star) in the upper reach of the River Fulda.