ECOLOGY OF FRESHWATERS

A VIEW FOR THE TWENTY-FIRST CENTURY

Brian Moss

Emeritus Professor, University of Liverpool, UK



CONTENTS

Ç

1 INTRODUCTION, 1

1.1 Why?, 1 Further reading. 8

2 WATER, A REMARKABLE UNREMARKABLE SUBSTANCE, 10

- 2.1 Introduction, 10
- 2.2 The molecular properties of water and their physical consequences, 12
 - 2.2.1 Ice and melting, 12
 - 2.2.2 Buffering and evaporation, 13
- 2.3 How much water is there and where is it?, 13
 - 2.3.1 Turnover and the hydrological cycle. 13
 - 2.3.2 Changes in geological time, 14
- 2.4 Patterns in hydrology, 15
 - 2.4.1 Temperate regions. 15
 - 2.4.2 Warm-temperate regions, 16
 - 2.4.3 Tropical cycles, 17
- 2.5 Bodies of water and their temperatures, 18
 - 2.5.1 Lakes and latitude. 18
 - 2.5.2 Deeper lakes, 21
 - 2.5.3 Effects of altitude and oceanicity, 21
- 2.6 Viscosity of water, fluid dynamics and the diffusion of gases, 22
 - 2.6.1 Diffusion, 24

Further reading, 24

3 WHY THE CHEMISTRY OF WATER IS SO IMPORTANT, 25

- 3.1 Introduction, 25
 - 3.1.1 Polar and covalent compounds. 25
- 3.2 The atmosphere, 26
 - 3.2.1 Carbon dioxide, 27
- 3.3 Major ions, 28
 - 3.3.1 Effects of ionic potential, 28
- 3.4 Global patterns in major ions: glaciation and endorheism. 30

- 3.4.1 The water chemistry of ancient landscapes, 31
- 3.4.2 Volcanic activity, 32
- 3.5 Open and closed basins, 34
- 3.6 The big picture, 35

Further reading, 36

4 MORE WATER CHEMISTRY: THE KEY NUTRIENTS, TRACE ELEMENTS AND ORGANIC MATTER, 37

- 4.1 Introduction, 37
- 4.2 Concepts of limiting substances. 37
- 4.3 Nutrients, 42
- 4.4 Phosphorus. 43
- 4.5 Nitrogen, 43
- 4.6 Pristine concentrations, 44
- 4.7 Trace elements and silicon, 45
- 4.8 Organic substances. 48
 - 4.8.1 Patterns in DOM availability, 48
- 4.9 Substance budgets. 50
- 4.10 Sediment–water relationships. 52

Further reading, 53

5 LIGHT THROWN UPON THE WATERS, 54

- 5.1 Light, 54
 - 5.1.1 Effects of the atmosphere, 55
- 5.2 From above to under the water, 56
- 5.3 From physics and chemistry to biology, 60 Further reading, 60

6 EVOLUTION AND DIVERSITY OF FRESHWATER ORGANISMS, 61

- 6.1 Introduction, 61
- 6.2 The ecological theatre and the evolutionary play. 62
 - 6.2.1 The seas form, 62
 - 6.2.2 Eukaryotic cells, 62

6.3	The freshwater biota, 64		7.10.3 Stream orders, 113			
	6.3.1 How many phyla and where?. 65		7.10.4 The River Continuum Concept, 113			
	6.3.2 Plants, 66		7.10.5 Invertebrates fall in too. 114			
	6.3.3 Animals, 67		7.10.6 and emerge, 114			
6.4	Living in freshwaters. 68		7.10.7 Indirectly, wolves are stream			
0.1	6.4.1 Osmoregulation, 69		animals, 114			
	6.4.2 Reproduction, 70		7.10.8 Scarcity of nutrients. 114			
	6.4.3 Resting stages and aestivation, 70		7.10.9 Salmon, 115			
	6.4.4 Getting enough oxygen. 72	7.11	Warm temperate streams, 117			
,	6.4.5 Insects, 73	7.12				
	6.4.6 Big animals. air breathers and	7.13	Tropical streams. 120			
	swamps, 73	Furth	er reading, 125			
6.5	Dispersal among freshwaters, 75		<i>D</i> -			
	6.5.1 Small things are the same		8 USES, MISUSES AND RESTORATION			
	everywhere?. 76	OF HEADWATER STREAMS AND				
	6.5.2 Or are they?, 76		RS, 127			
	6.5.3 Vulnerability and dispersal in	8.1	Traditional use of headwater river			
	freshwaters, 76		systems, 127			
6.6	Patterns in freshwater diversity, 78	8.2	Deforestation, 129			
	6.6.1 Fish faunas, 78	8.3	Acidification, 130			
6.7	The fish of Lake Victoria, 84	8.4	Eutrophication, 134			
	Low diversity freshwater habitats. 84		Commercial afforestation, 136			
	6.8.1 Caves. 85	8.5 8.6	Settlement, 136			
6.9	A summary of the freshwater biota and its		Engineering impacts, 138			
	problems. 86	8.8	Alterations of the fish community by man, 139			
Further reading, 87			Sewage, toxic pollution and their treatment, 141			
7 HI	EADWATER STREAMS AND	8.10	Diffuse pollution. 143			
RIVERS, 89			River monitoring, 147			
7.1	Introduction, 89	8.12	The Water Framework Directive, 148			
7.2	General models of stream ecosystems. 89	8.13	Implementation of the Directive, 150			
7.3	A basic lesson in stream flow, 92	8.14	Wider considerations: ecosystem services, 151			
7.4	Flow and discharge, 92	8.15	Restoration, rehabilitation and reconciliation			
7.5	Laminar and turbulent flow, 93		ecology, 151			
7.6	Particles carried, 94	8.16	Reconciliation ecology of river systems, 154			
7.7	The response of stream organisms to shear	Further reading, 156				
	stress, 95		_			
7.8	Community composition in streams, 96	9 M	IDDLE STAGE AND DEPOSITIONAL			
	7.8.1 Algal and plant communities. 97	FLO	ODPLAIN RIVERS, 157			
	7.8.2 Macroinvertebrates, 98	9.1	Introduction, 157			
7.9	Streams in cold climates: the polar and alpine		Change from an erosive river to a depositional			
	zones, 102		one. 158			
	7.9.1 Invertebrates of kryal streams, 104	9.3	Submerged plants. 160			
	7.9.2 Primary producers, 104	9.4	Growth of submerged plants, 162			
	7.9.3 Food webs in cold streams, 105	9.5	Methods of measuring the primary			
	7.9.4 Fish and birds in polar streams, 107		productivity of submerged plants, 164			
7.10	Stream systems in the cold temperate zone, 109		9.5.1 Whole community methods, 164			
	7.10.1 Allochthonous sources of energy, 111		9.5.2 Enclosure methods. 165			
	7.10.2 Shredders, filter-collectors and deposit		9.5.3 Other methods, 166			
	feeders, 112	9.6	Submerged plants and the river ecosystem. 167			

9.7 Further downstream – swamps and 11.7.2 Organic remains. 236				
floodplains. 167 11.7.3 General problems of interpr	retation			
9.7.1 Productivity of swamps and of evidence from sediment				
floodplain marshes, 169 cores. 238				
9.7.2 Swamp soils and the fate of the high 11.7.4 So what has the history bee	en?			
primary production, 170 Two ancient lakes, 239				
9.7.3 Oxygen supply and soil chemistry in 11.7.5 Younger lakes. 241				
swamps. 171 11.8 Filling in, 242				
9.7.4 Emergent plants and flooded soils. 172 11.9 Summing up. 243				
9.8 Swamp and marsh animals, 173 Further reading, 244				
9.8.1 Whitefish and blackfish, 174				
9.9 Latitudinal differences in floodplains. 176 12 THE COMMUNITIES OF SHALL	12 THE COMMUNITIES OF SHALLOW			
9.9.1 Polar floodplains. 176 STANDING WATERS: MIRES, SHAL	.LOW			
9.9.2 Cold temperate floodplains. 177 LAKES AND THE LITTORAL ZONE,	245			
9.9.3 Warm temperate floodplains. 179 12.1 Introduction. 245				
9.9.4 Tropical floodplains. 180 12.2 The scope of mires and littoral zones, 24	16			
9.9.5 The Sudd, 183 12.2.1 Temperature. 246				
Further reading, 185 12.2.2 Nutrients, 247				
12.2.3 Littoral communities in lakes,	, 250			
10 FLOODPLAIN ECOSYSTEMS AND 12.3 The structure of littoral communities, 2	253			
HUMAN AFFAIRS, 186 12.4 Heterotrophs among the plants. 256				
10.1 Introduction, 186 12.4.1 Neuston, 260				
10.2 Floodplain services, 189 12.5 Linkages, risks and insurances among	the			
10.2.1 Floodplain fisheries. 192 littoral communities. 260				
10.3 Floodplain swamps and human 12.6 Latitude and littorals, 262				
diseases. 193 12.7 The role of the nekton, 262				
10.4 Case studies. 196 12.8 Further reading. 265				
10.4.1 The Florida Everglades, 196				
10.4.2 The Pongola river, 200 13 PLANKTON COMMUNITIES OF	THE			
10.5 River and floodplain management and PELAGIC ZONE, 267				
rehabilitation, 204 13.1 Kitchens and toilets, 267				
10.5.1 Plant bed management in rivers, 204 13.2 Phytoplankton, 268				
10.5.2 Mitigation and enhancement, 206 13.2.1 Photosynthesis and growth o	f			
10.5.3 Rehabilitation, 209 phytoplankton, 271				
10.6 Interbasin transfers and water needs. 211 13.2.2 Net production and growth, 2				
10.6.1 Assessment of the water needs. 211 13.2.3 Nutrient uptake and growth r	ates of			
Further reading, 214 phytoplankton, 273				
13.2.4 Distribution of freshwater				
11 LAKES AND OTHER STANDING phytoplankton, 275				
WATERS, 216 13.2.5 Washout, 275				
11.1 Introduction, 216 13.2.6 Cyanobacterial blooms, 276				
11.2 The origins of lake basins, 217 13.3 Heterotrophs in the plankton: viruses a	ınd			
11.3 Lake structure, 219 bacteria, 279				
11.4 The importance of the catchment area, 223 13.4 Protozoa and fungi, 281	Protozoa and fungi, 281			
11.5 Lakes as autotrophic or heterotrophic 13.5 Zooplankton. 283				
systems. 224 13.5.1 Grazing. 285				
11.6 The continuum of lakes, 227 13.5.2 Feeding and grazing rates of				
11.7 Lake history. 233 zooplankton, 288				
11.7.1 The methods of 13.5.3 Competition among grazers, 2				
palaeolimnology, 234 13.5.4 Predation in the zooplankton.	289			

15.4.2

The East African Great Lakes, 340

		Predation on zooplankters by	15.5	Fish cult	
		zooplankters, 290	15.6		er angling, 349
13.6	Fish in the open-water community, 293		15.7	Amenity	culture and the aquarium trade. 351
	13.6.1 Predation on the zooplankton and fish		15.8	Domesti	c water supply, eutrophication and
		production, 293		reservoii	rs, 352
	13.6.2	Avoidance of vertebrate predation by		15.8.1	Eutrophication – human induced
		the zooplankton. 296			changes in the production
13.7	Piscivore:	s and piscivory. 298			of lakes, 353
13.8	Functioning of the open-water		•	15.8.2	Dams and reservoirs. 358
	community. 299			15.8.3	Fisheries in new lakes, 359
	13.8.1	Polar lakes, 300		15.8.4	Effects downstream of the new
	13.8.2	Cold temperate lakes, 301			lake. 360
	13.8.3	Warm temperate lakes, 303		15.8.5	New tropical lakes and human
	13.8.4	Very warm lakes in the tropics, 305			populations, 360
Furth	er reading.	307		15.8.6	Man-made tropical lakes, the
					balance of pros and cons, 361
14 T	HE PRO	FUNDAL ZONE, 308	15.9	Amenity	and conservation, 363
14.1	The end o	of the line, 308	15.10	Restorat	ion approaches for standing waters:
14.2	The impo	rtance of oxygen, 309		sympton	n treatment. 367
14.3	Profunda	l communities, 310	15.11	Treatme	ent of proximate causes: nutrient
14.4	Biology of	f selected benthic invertebrates, 312		control.	370
	14.4.1	Chironomus anthracinus,		15.11.1	Present supplies of phosphorus.
	*	a detritivore, 312			their relative contributions and
	14.4.2	Chaoborus flavicans, a predator, 314		1	how they are related to the
14.5	What the	sediment-living detritivores			algal crop, 370
	really eat	. 315		15.11.2	Methods available for reducing
14.6	Influence	of the open water community on			total phosphorus loads, 371
	the profu	ndal benthos. 316		15.11.3	
Furth	er reading.	321		15.11.4	Complications for phosphorus
					control – sediment sources, 374
		S, ABUSES AND		15.11.5	
		ON OF STANDING			creation, 376
	ERS, 32		Furthe	r reading.	377
15.1		ction, 322			
15.2		provided by standing waters, 324	16 CLIMATE CHANGE AND THE FUT		
15.3	Fisheries, 325				ATERS, 380
	15.3.1	Some basic fish biology. 326			hant of Venice, 380
	15.3.2	Eggs, 326			nange, 381
	15.3.3	Feeding, 328			ffects of freshwaters, 383
	15.3.4	Breeding, 329	16.4	Future effe	
	15.3.5	Choice of fish for a fishery. 332			Future effects on freshwaters, 389
	15.3.6	Measurement of fish			Switches and feedbacks. 397
		production, 332			nd mitigation of global warming, 400
	15.3.7	Growth measurement, 333			dy of ultimate causes. 402
	15.3.8	Fish production and commercial	Furthe	r reading.	408
		fisheries in lakes. 334			
15.4	_	s in fisheries: two case studies, 338			I EXERCISES, 411
	15.4.1	The North American Great	Exercis		ratification. 411
		Lakes, 339	Exercis	se 2. Ca	tchments and water chemistry, 412

Exercise 3.

The Vollenweider model, 412

Exercise 4.	Nutrient budgeting, 413	Exercise 14.	The plankton of paddling pools. 423		
Exercise 5.	Light penetration, 415	Exercise 15.	Probing the profundal, 427		
Exercise 6.	Biodiversity. 416	Exercise 16.	The curse of birds for lake		
Exercise 7.	Problems with a frog, 416		managers, 428		
Exercise 8.	Predation in streams, 417	Exercise 17.	Nutrient problems in tricky		
. Exercise 9.	Deforestation and tropical streams, 417		situations, 430		
Exercise 10.	Swamp habitats and insect				
	adaptations, 417	References, 4	-32		
Exercise 11.	Ecosystem valuation in a				
	floodplain. 420	Index. 454	~		
Exercise 12.	Top down and bottom up control in				
	shallow and deep lakes, 423	Companion website for this book:			
Exercise 13. Palatability of aquatic plants to fish, 423		www.wiley.com/go/moss/ecology			