

# Table of Contents

Preface .....	xi
Acknowledgments.....	xxiii
<b>Chapter 1</b> Introduction .....	1
<b>Chapter 2</b> Basic Concepts and Terminology .....	7
2.1 Introduction.....	7
2.2 Chemistry.....	7
2.2.1 Aqueous Chemistry .....	7
2.2.1.1 Concentration Units .....	7
2.2.2 Acids and Bases.....	8
2.2.3 Equilibrium Constant .....	9
2.2.4 Thermodynamics.....	9
2.2.4.1 Influence of pH.....	12
2.2.5 Oxidation–Reduction Reactions.....	13
2.2.5.1 Oxidation–Reduction .....	13
2.2.5.2 Oxidation State or Number .....	13
2.2.6 Balancing Oxidation–Reduction Reactions .....	13
2.3 Microbiology and Biochemistry .....	15
2.3.1 Microbial Cell.....	15
2.3.2 Microbial Classification .....	16
2.3.3 Chemistry of Biological Molecules.....	16
2.3.4 Metabolic Reactions .....	16
2.3.5 Enzymes .....	17
2.3.6 Biochemical Kinetics .....	17
2.4 Isotopes .....	18
2.4.1 Radioactive Isotopes and Decay.....	18
2.4.2 Half-Life .....	18
2.4.3 Stable Isotopes .....	19
2.5 Terminology in Soil Science .....	19
2.5.1 Master Soil Horizon .....	19
2.5.2 Properties Used in Soil Description .....	20
2.5.3 Soil Taxonomy.....	21
2.5.4 Physical Properties .....	23
2.5.5 Chemical Properties .....	24
2.6 Units .....	24
Study Questions .....	25
Further Readings.....	26
<b>Chapter 3</b> Biogeochemical Characteristics .....	27
3.1 Introduction.....	27
3.2 Types of Wetlands .....	31
3.2.1 Coastal Wetlands.....	31
3.2.2 Inland Wetlands.....	32
3.3 Wetland Hydrology .....	34

3.4	Wetland Soils .....	35
3.4.1	Physical Characteristics.....	36
3.4.2	Chemical Characteristics.....	38
3.4.3	Biological Characteristics.....	40
3.5	Wetland Vegetation .....	41
3.6	Biogeochemical Features of Wetlands.....	41
3.6.1	Presence of Molecular Oxygen in Restricted Zones .....	42
3.6.2	Sequential Reduction of Other Inorganic Electron Acceptors.....	42
3.6.3	Oxidized Soil–Floodwater Interface .....	43
3.6.4	Exchanges at the Soil–Water Interface .....	45
3.6.5	Presence of Hydrophytic Vegetation .....	46
3.7	Types of Wetland/Hydric Soils .....	46
3.7.1	Waterlogged Mineral Soils.....	46
3.7.2	Organic Soils (Histosols).....	51
3.7.3	Marsh Soils.....	52
3.7.4	Paddy Soils .....	53
3.7.5	Subaqueous Soils .....	53
3.8	Field Indicators of Hydric Soils .....	54
3.8.1	All Soils .....	55
3.8.2	Sandy Soils .....	58
3.8.3	Loamy and Clayey Soils.....	60
3.9	Summary .....	63
	Study Questions .....	64
	Further Readings.....	65
Chapter 4	Electrochemical Properties.....	67
4.1	Introduction .....	67
4.2	Theoretical Relationships.....	69
4.2.1	$E^\circ$ vs. $\log K$ .....	76
4.2.2	$pe$ vs. $Eh$ .....	77
4.3	Measurement of Eh .....	79
4.4	Eh–pH Relationships.....	81
4.5	Buffering of Redox Potential (Poise) .....	84
4.6	Measurement of Redox Potentials .....	85
4.6.1	Construction of Platinum Electrodes .....	85
4.6.2	Standardization of Electrodes .....	86
4.6.3	Redox Potentials in Soils.....	88
4.7	pH.....	92
4.7.1	Soil pH.....	93
4.7.2	Floodwater pH .....	96
4.7.3	pH Effects .....	97
4.8	Redox Couples in Wetlands .....	98
4.8.1	Intensity .....	99
4.8.2	Capacity .....	100
4.9	Redox Gradients in Soils.....	101
4.10	Microbial Fuel Cells.....	106
4.11	Specific Conductance.....	106
4.12	Summary .....	107
	Study Questions .....	108
	Further Readings.....	109

<b>Chapter 5 Carbon .....</b>	111
5.1 Introduction.....	111
5.2 Major Components of Carbon Cycle in Wetlands .....	114
5.2.1 Plant Biomass Carbon (Net Primary Productivity).....	114
5.2.2 Particulate Organic Matter (Detrital and Soil).....	115
5.2.3 Microbial Biomass Carbon.....	116
5.2.4 Dissolved Organic Matter.....	117
5.2.5 Gaseous Forms of Carbon .....	118
5.3 Organic Matter Accumulation .....	119
5.4 Characteristics of Detritus and Soil Organic Matter .....	121
5.4.1 Nonhumic Substances .....	122
5.4.1.1 Carbohydrates .....	122
5.4.2 Phenolic Substances .....	125
5.4.3 Humic Substances .....	127
5.5 Decomposition .....	129
5.5.1 Leaching and Fragmentation .....	129
5.5.2 Extracellular Enzyme Hydrolysis.....	130
5.5.3 Catabolic Activity .....	136
5.5.3.1 Aerobic Catabolism.....	138
5.5.3.2 Anaerobic Catabolism.....	141
5.5.3.3 Aerobic vs. Anaerobic Catabolism.....	150
5.6 Organic Matter Turnover .....	151
5.6.1 Abiotic Decomposition.....	151
5.6.2 Biotic Decomposition .....	153
5.7 Regulators of Organic Matter Decomposition.....	157
5.7.1 Quality and Quantity of Organic Matter.....	158
5.7.2 Microbial Communities and Biomass .....	160
5.7.3 Water Table or Soil Aeration Status .....	162
5.7.4 Availability of Electron Acceptors with Higher Reduction Potentials.....	164
5.7.5 Nutrient Availability.....	167
5.7.6 Temperature.....	170
5.8 Environmental and Ecological Significance .....	173
5.9 Functions of Organic Matter in Soils.....	178
5.10 Summary.....	180
Study Questions .....	183
Further Readings.....	184
<b>Chapter 6 Oxygen.....</b>	185
6.1 Introduction.....	185
6.2 Oxygen–H <sub>2</sub> O Redox Couple .....	186
6.3 Soil Gases.....	187
6.3.1 Redox Potential.....	192
6.3.2 Oxygen Diffusion Rate.....	195
6.3.3 Soil Oxygen Content.....	198
6.4 Sources of Oxygen .....	199
6.5 Aerobic–Anaerobic Interfaces .....	200
6.6 Oxygen Consumption .....	204
6.6.1 Oxygen as Reactant .....	204
6.6.2 Oxygen as an Electron Acceptor .....	205

6.7 Summary.....	211
Study Questions.....	212
Further Readings.....	212
<b>Chapter 7 Adaptation of Plants to Soil Anaerobiosis.....</b>	<b>215</b>
7.1 Introduction.....	215
7.2 Distribution of Wetland Plants.....	217
7.3 Mechanisms of Flood Tolerance.....	218
7.3.1 Metabolic Adaptations .....	219
7.3.2 Morphological/Anatomical Adaptations .....	221
7.3.2.1 Roots .....	221
7.3.2.2 Pneumatophores.....	221
7.3.2.3 Lenticels .....	222
7.3.2.4 Intercellular Airspaces.....	222
7.3.3 Aerenchyma Formation .....	223
7.3.4 Intercellular Oxygen Concentration .....	226
7.4 Mechanisms of Oxygen Movement in Wetland Plants.....	227
7.4.1 Diffusion.....	228
7.4.2 Mass Flow.....	229
7.5 Oxygen Release by Plants .....	237
7.6 Measurement of Radial Oxygen Loss .....	239
7.7 Soil Phytotoxic Accumulation Effects on Plant Growth .....	241
7.8 Oxidizing Power of Plant Roots.....	245
7.8.1 Root Iron Plaque Formation .....	246
7.9 Effect of Intensity and Capacity of Soil Reduction on Wetland Plant Functions.....	247
7.9.1 Effect of Soil Reduction Intensity .....	249
7.9.2 Relationship of Reduction Intensity with Root Porosity and Radial Oxygen Loss.....	250
7.9.3 Effect of Soil Reduction Intensity on Nutrient Uptake .....	252
7.9.4 Soil Reduction Capacity Effects on Carbon Assimilation and Radial Oxygen Loss.....	253
7.10 Summary.....	255
Study Questions.....	256
Further Readings.....	256
<b>Chapter 8 Nitrogen .....</b>	<b>257</b>
8.1 Introduction.....	257
8.2 Forms of Nitrogen.....	257
8.2.1 Inorganic Nitrogen.....	257
8.2.2 Organic Nitrogen .....	258
8.3 Major Storage Compartments .....	258
8.3.1 Plant Biomass Nitrogen .....	260
8.3.2 Particulate Organic Nitrogen.....	260
8.3.3 Microbial Biomass Nitrogen.....	261
8.3.4 Dissolved Organic Nitrogen .....	261
8.3.5 Inorganic Forms of Nitrogen .....	261
8.3.6 Gaseous End Products.....	261
8.4 Redox Transformations of Nitrogen.....	262
8.5 Mineralization of Organic Nitrogen .....	264

8.5.1 C:N Ratio Concept.....	265
8.5.2 Chemical Composition of Organic Nitrogen.....	267
8.5.3 Microbial Degradation of Organic Nitrogen .....	274
8.5.4 Regulators of Organic Nitrogen Mineralization .....	278
8.6 Ammonia Adsorption–Desorption .....	280
8.7 Ammonia Fixation .....	283
8.8 Ammonia Volatilization.....	284
8.8.1 Physicochemical Reaction.....	284
8.8.2 Regulators of Ammonia Volatilization .....	286
8.9 Nitrification .....	289
8.9.1 Chemoautotrophic Bacteria.....	289
8.9.2 Methane-Oxidizing Bacteria.....	291
8.9.3 Heterotrophic Bacteria and Fungi.....	292
8.9.4 Regulators of Ammonium Oxidation .....	292
8.10 Anaerobic Ammonium Oxidation .....	294
8.11 Nitrate Reduction .....	296
8.11.1 Denitrification .....	297
8.11.2 Nitrifier Denitrification .....	298
8.11.3 Aerobic Denitrification.....	301
8.11.4 Chemodenitrification.....	301
8.11.5 Dissimilatory Nitrate Reduction to Ammonia (DNRA).....	302
8.11.6 Regulators of Nitrate Reduction.....	303
8.11.7 Nitrate Reduction Rates in Wetlands and Aquatic Systems.....	307
8.12 Nitrogen Fixation .....	309
8.12.1 Regulators of Dinitrogen Fixation .....	310
8.12.2 Nitrogen Fixation Rates.....	313
8.13 Nitrogen Assimilation by Vegetation .....	314
8.14 Nitrogen Processing by Wetlands .....	317
8.14.1 Ammonium Flux .....	318
8.14.2 Nitrate Flux .....	320
8.15 Summary.....	322
Study Questions .....	322
Further Readings.....	323
<b>Chapter 9 Phosphorus.....</b>	<b>325</b>
9.1 Introduction.....	325
9.2 Phosphorus Accumulation in Wetlands .....	328
9.2.1 Why Does Phosphorus Added to Wetlands Accumulate in Soils?.....	328
9.3 Phosphorus Forms in Water Column and Soil.....	330
9.3.1 Water Column .....	332
9.3.2 Soil.....	334
9.4 Inorganic Phosphorus.....	335
9.5 Phosphorus Sorption by Soils .....	340
9.5.1 Adsorption—Desorption.....	343
9.5.2 Phosphorus Sorption Isotherms .....	346
9.5.2.1 Linear Equation.....	347
9.5.2.2 Freundlich Equation.....	348
9.5.2.3 Langmuir Equation .....	349

9.5.2.4 Single-Point Isotherms.....	349
9.5.2.5 Quantity ( <i>Q</i> )/Intensity ( <i>I</i> ) Relationships.....	350
9.5.3 Precipitation and Dissolution .....	350
9.5.4 Regulators of Phosphorus Retention and Release.....	353
9.6 Organic Phosphorus.....	357
9.6.1 Forms of Organic Phosphorus.....	357
9.6.2 Chemical Characterization of Organic Phosphorus.....	367
9.7 Phosphorus Uptake and Storage in Biotic Communities.....	370
9.7.1 Microorganisms.....	370
9.7.2 Periphyton.....	371
9.7.3 Vegetation.....	372
9.8 Mineralization of Organic Phosphorus.....	376
9.8.1 Abiotic Degradation and Stabilization of Organic Phosphorus .....	377
9.8.1.1 Leaching of Soluble Organic Phosphorus.....	377
9.8.1.2 Noncatalyzed Hydrolysis of Phosphate Esters.....	377
9.8.1.3 Photolysis .....	378
9.8.1.4 Stabilization of Organic Phosphorus .....	378
9.8.2 Enzymatic Hydrolysis of Organic Phosphorus.....	378
9.8.2.1 Phosphatases or Monoesterases .....	379
9.8.2.2 Phosphodiesterases.....	381
9.8.3 Microbial Activities and Phosphorus Release.....	381
9.8.3.1 Litterbag Method.....	384
9.8.3.2 Basal Mineralization of Organic Phosphorus.....	384
9.8.3.3 Potentially Mineralizable Phosphorus .....	384
9.8.3.4 Mineralization of Added Organic Phosphorus .....	385
9.8.3.5 Substrate-Induced Organic Phosphorus Mineralization .....	385
9.8.4 Regulators of Organic Phosphorus Mineralization.....	387
9.9 Biotic and Abiotic Interactions on Phosphorus Mobilization.....	388
9.9.1 Phosphorus–Iron–Sulfur Interactions .....	388
9.9.2 Periphyton–Phosphate Interactions .....	391
9.9.3 Biotic and Abiotic Interactions of Fe and Ca with Phosphorus .....	394
9.9.4 Gaseous Loss of Phosphorus.....	395
9.10 Phosphorus Exchange between Soil and Overlying Water Column .....	395
9.11 Phosphorus Memory by Soils and Sediments.....	397
9.12 Summary.....	401
Study Questions .....	403
Further Readings.....	403
<b>Chapter 10 Iron and Manganese.....</b>	<b>405</b>
10.1 Introduction .....	405
10.2 Storage and Distribution.....	405
10.3 Eh–pH Relationships .....	407
10.3.1 Iron.....	409
10.3.2 Manganese .....	411
10.4 Reduction of Iron and Manganese.....	411
10.4.1 Microbial Communities .....	413
10.4.2 Biotic and Abiotic Reduction.....	415
10.4.2.1 Biotic Reduction .....	415
10.4.2.2 Abiotic Reduction.....	417

10.4.3 Forms of Iron and Manganese .....	421
10.4.3.1 Iron .....	422
10.4.3.2 Manganese.....	423
10.4.3.3 Complexation of Iron and Manganese with Dissolved Organic Matter .....	425
10.4.3.4 Mobile and Immobile Pools of Iron and Manganese.....	425
10.5 Oxidation of Iron and Manganese .....	427
10.5.1 Microbial Communities .....	428
10.5.2 Biotic and Abiotic Oxidation .....	429
10.5.2.1 Iron.....	430
10.5.2.2 Manganese .....	432
10.6 Mobility of Iron and Manganese .....	432
10.7 Ecological Significance.....	435
10.7.1 Nutrient Regeneration/Immobilization.....	435
10.7.1.1 Organic Matter Decomposition and Nutrient Release.....	435
10.7.1.2 Phosphorous Release or Retention.....	438
10.7.1.3 Coprecipitation of Trace Elements with Iron and Manganese Oxides.....	439
10.7.2 Ferromanganese Nodules.....	439
10.7.3 Root Plaque Formation .....	440
10.7.4 Ferrolysis.....	441
10.7.5 Methane Emissions.....	441
10.8 Summary.....	443
Study Questions .....	444
Further Readings.....	445
<b>Chapter 11 Sulfur .....</b>	<b>447</b>
11.1 Introduction .....	447
11.2 Major Storage Compartments.....	447
11.3 Forms of Sulfur .....	448
11.4 Oxidation–Reduction of Sulfur .....	451
11.5 Assimilatory Sulfate and Elemental Sulfur Reduction .....	454
11.6 Mineralization of Organic Sulfur.....	454
11.7 Electron Acceptor—Reduction of Inorganic Sulfur .....	457
11.7.1 Dissimilatory Sulfate Reduction .....	457
11.7.2 Role of Sulfur in Energy Flow .....	461
11.7.3 Measurement of Sulfate Reduction in Wetland Soils.....	462
11.7.4 Regulators of Sulfate Reductions .....	464
11.8 Electron Donor—Oxidation of Sulfur Compounds .....	466
11.9 Biogenic Emission of Reduced Sulfur Gases.....	470
11.10 Sulfur–Metal Interactions .....	471
11.11 Sulfide Toxicity.....	473
11.12 Exchange between Soil and Water Column .....	473
11.13 Sulfur Sinks .....	474
11.14 Summary .....	475
Study Questions .....	475
Further Readings.....	476
<b>Chapter 12 Metals/Metalloids .....</b>	<b>477</b>
12.1 Introduction .....	477
12.2 Factors Governing Metal Availability and Transformation .....	477
12.2.1 Soil/Sediment Redox–pH Conditions.....	480

12.3 Mercury—Methyl Mercury .....	482
12.4 Arsenic.....	485
12.4.1 Sources of Arsenic.....	485
12.4.2 Dissolution of Primary Minerals.....	485
12.4.3 Biotransformation.....	486
12.4.3.1 Thermodynamics .....	486
12.4.4 Oxidation–Reduction .....	486
12.4.5 Reductive Dissolution of Metal Oxides.....	487
12.4.6 Kinetics of Arsenic Oxidation–Reduction in Soils.....	487
12.4.7 Importance of As Speciation.....	487
12.4.7.1 Competition with Other Anions.....	488
12.4.7.2 Coprecipitation with Metal Oxides and Sulfide.....	489
12.4.8 Chemical Oxidation and Reduction of Arsenic .....	489
12.4.8.1 Oxidation by Metal Oxides.....	489
12.4.8.2 Reduction by Sulfides.....	489
12.5 Copper .....	489
12.6 Zinc.....	493
12.6.1 Distribution in Soils and Sediments.....	493
12.7 Selenium .....	494
12.8 Chromium.....	496
12.9 Cadmium .....	499
12.10 Lead.....	501
12.11 Nickel.....	503
12.12 Summary .....	505
Study Questions .....	505
Further Readings.....	506
<b>Chapter 13 Toxic Organic Compounds .....</b>	<b>507</b>
13.1 Introduction .....	507
13.1.1 Pharmaceuticals.....	511
13.2 Biotic Pathways .....	513
13.2.1 Acclimation .....	514
13.2.2 Biodegradation .....	514
13.2.3 Cometabolism.....	514
13.2.4 Microbial Accumulation.....	514
13.2.5 Polymerization and Conjugation .....	514
13.3 Metabolism of Organic Compounds .....	515
13.3.1 Hydrolysis.....	515
13.3.2 Oxidation .....	516
13.3.2.1 Hydroxylation.....	516
13.3.2.2 Dealkylation.....	517
13.3.2.3 $\beta$ -Oxidation .....	517
13.3.2.4 Decarboxylation .....	517
13.3.2.5 Cleavage of Ether Linkage .....	518
13.3.2.6 Epoxidation .....	518
13.3.2.7 Oxidative Coupling .....	518
13.3.2.8 Aromatic Ring Cleavage .....	518
13.3.2.9 Heterocyclic Ring Cleavage .....	518
13.3.2.10 Sulfoxidation .....	518

13.3.3 Reduction.....	519
13.3.3.1 Reductive Dehalogenation .....	519
13.3.4 Synthesis.....	520
13.4 Plant and Microbial Uptake.....	521
13.5 Abiotic Pathways .....	521
13.5.1 Redox–Potential–pH.....	521
13.5.2 Hydrolysis .....	522
13.5.3 Sorption to Suspended Solids and the Substrate Bed.....	522
13.5.3.1 Effect of Colloidal Organic Matter in Surface Water on Sorption in Wetlands.....	524
13.5.4 Exchange between Soil and Water Column .....	525
13.5.5 Settling and Burial of Particulate Contaminants .....	525
13.5.6 Photolysis.....	525
13.5.7 Volatilization .....	526
13.5.8 Runoff and Leaching.....	527
13.6 Regulators.....	528
13.6.1 Effect of Electron Acceptors on Toxic Organic Degradation .....	528
13.6.2 Denitrifying Bacteria.....	528
13.6.3 Effect of Sediment Redox–pH Conditions on Degradation .....	529
13.6.4 Burial .....	533
13.7 Summary .....	533
Study Questions .....	534
Further Readings.....	535
<b>Chapter 14 Soil and Floodwater Exchange Processes.....</b>	<b>537</b>
14.1 Introduction .....	537
14.2 Advective Flux.....	539
14.2.1 Advective Flux Processes.....	539
14.2.2 Measurement of Advective Flux .....	540
14.2.2.1 Seepage Meters .....	541
14.2.2.2 Piezometer.....	542
14.2.2.3 Salinity/Conductivity .....	542
14.2.2.4 Radium/Radon Isotopes.....	542
14.2.2.5 Dyes.....	543
14.2.3 Diffusive Flux.....	543
14.3.1 Diffusive Flux Processes.....	543
14.3.1.1 Ammonium Flux.....	545
14.3.1.2 Phosphate Flux.....	546
14.3.1.3 Sulfate Flux.....	546
14.4 Bioturbation .....	547
14.4.1 Macrofauna Communities .....	548
14.4.2 Benthic Invertebrates and Sediment–Water Interactions .....	549
14.5 Wind Mixing and Resuspension.....	550
14.6 Exchange of Dissolved Solutes between Soil/Sediment and the Water Column .....	551
14.6.1 Gradient-Based Measurements.....	552
14.6.2 Overlying Water Incubations.....	552
14.6.2.1 Benthic Chambers.....	552
14.6.2.2 Intact Cores .....	554

14.7	Sediment Transport Processes.....	556
14.7.1	Sediment/Organic Matter Accretion in Wetlands .....	557
14.7.2	Measurement of Sedimentation or Accretion Rates.....	560
14.7.2.1	Filter Pad Traps .....	562
14.7.2.2	Artificial Marker Horizons .....	562
14.7.2.3	Sedimentation–Erosion Table .....	563
14.7.2.4	Beryllium-7 Dating .....	564
14.7.2.5	Lead-210 Dating.....	565
14.7.2.6	Cesium-137 Dating.....	566
14.7.2.7	Carbon-14 Dating .....	567
14.7.2.8	Application of Sediment Dating .....	568
14.8	Vegetative Flux/Detrital Export.....	568
14.9	Air–Water Exchange.....	569
14.10	Biogeochemical Regulation of Exchange Processes.....	570
14.11	Summary .....	572
	Study Questions .....	573
	Further Readings.....	573
	<b>Chapter 15 Biogeochemical Indicators .....</b>	<b>575</b>
15.1	Introduction .....	575
15.2	Concept of Indicators .....	577
15.3	Guidelines for Indicator Development .....	578
15.3.1	Conceptual Relevance .....	578
15.3.2	Feasibility of Implementation.....	578
15.3.3	Response Variability .....	579
15.3.4	Interpretation and Utility.....	579
15.4	Levels of Indicators .....	579
15.5	Wetland Ecosystem Reference Conditions.....	581
15.6	Sampling Protocol and Design.....	582
15.6.1	Water Quality Indicators .....	588
15.6.2	Soil Quality Indicators .....	588
15.6.3	Minimum Monitoring Requirements .....	590
15.7	Data Analysis.....	590
15.7.1	Impact/Recovery Indices.....	594
15.8	Summary .....	597
	Study Questions .....	597
	Further Readings.....	598
	<b>Chapter 16 Wetlands and Global Climate Change.....</b>	<b>599</b>
16.1	Introduction .....	599
16.2	Potential Impact of Global Change to Wetlands .....	601
16.3	Methane .....	602
16.3.1	Wetlands as a Source of Methane .....	602
16.3.2	Methane Production in Wetlands .....	603
16.3.3	Methane Emission .....	604
16.3.4	Regulators of Methane Emission .....	607
16.3.5	Methane Sinks .....	608

16.4	Nitrous Oxide .....	609
16.4.1	Wetlands as a Source of Nitrous Oxide.....	609
16.4.2	Nitrous Oxide Production in Wetlands.....	609
16.4.3	$\text{N}_2\text{O}$ Emission from Wetlands .....	611
16.4.4	Production and Emissions from Natural Wetlands .....	611
16.4.5	Regulators of $\text{N}_2\text{O}$ Production and Emissions .....	613
16.4.6	Nitrous Oxide Consumption.....	614
16.5	Carbon Sequestration .....	615
16.6	Impact of Sea-Level Rise on Coastal Wetlands .....	616
16.6.1	Marsh Accretion .....	619
16.7	Summary .....	620
	Study Questions .....	620
	Further Readings.....	621
<b>Chapter 17</b>	<b>Freshwater Wetlands: The Everglades .....</b>	<b>623</b>
17.1	Introduction .....	623
17.2	Everglades Wetlands.....	625
17.2.1	Historical Perspective.....	626
17.2.2	Hydrologic Units.....	627
17.2.2.1	Everglades Agricultural Area and C-139 Basin .....	627
17.2.2.2	Stormwater Treatment Areas .....	629
17.2.2.3	Water Conservation Areas .....	629
17.2.2.4	Holeyland and Rotenberger Wildlife Management Areas .....	630
17.2.2.5	Everglades National Park .....	630
17.3	Nutrient Loads and Ecological Alterations .....	630
17.3.1	Surface Water Quality and Loads .....	631
17.3.2	Soil Nutrient Distribution and Storage .....	633
17.3.3	Vegetation.....	639
17.3.4	Periphyton.....	641
17.3.5	Microbial Communities and Biomass .....	643
17.3.5.1	Microbial Communities .....	643
17.3.5.2	Microbial Biomass .....	645
17.4	Biogeochemical Cycles.....	647
17.4.1	Enzymes .....	647
17.4.2	Carbon Cycling.....	649
17.4.2.1	Decomposition of Organic Matter .....	649
17.4.2.2	Microbial Respiration .....	649
17.4.2.3	Methane Emissions .....	651
17.4.3	Nitrogen Cycling .....	653
17.4.3.1	Organic Nitrogen Mineralization.....	653
17.4.3.2	Nitrification–Denitrification .....	655
17.4.3.3	Biological Nitrogen Fixation.....	656
17.4.4	Phosphorus Cycling.....	657
17.4.4.1	Biotic Processes .....	658
17.4.4.2	Abiotic Processes .....	659
17.4.5	Sulfur Cycling .....	660
17.4.5.1	The Methylmercury–Sulfate Link .....	663

17.5	Restoration and Recovery.....	663
17.6	Summary .....	666
	Study Questions .....	667
	Further Readings.....	667
<b>Chapter 18 Coastal Wetlands: Mississippi River Deltaic Plain</b>		
	<b>Coastal Marshes, Louisiana.....</b>	<b>669</b>
18.1	Introduction .....	669
18.2	Biogeography and Geology of Louisiana Coastal Wetlands .....	669
18.3	Coastal Wetland Loss .....	670
18.4	Case Studies .....	672
18.4.1	Processes Governing Coastal Marsh Stability .....	672
18.4.2	Comparison of Vertical Accretion of Louisiana Marsh to Other Gulf Coast Marsh.....	673
18.4.3	Influence of Sediment Addition to a Deteriorating Louisiana Salt Marsh.....	676
18.4.4	Impact of Mississippi River Diversion on Enhancing Marsh Accretion .....	676
18.5	Impact of Flooding and Saltwater Intrusion on Louisiana Coastal Vegetation .....	680
18.6	Carbon Cycling.....	684
18.6.1	Primary Production .....	684
18.6.2	Methane and Carbon Dioxide Emission along a Salinity Gradient in Louisiana Coastal Marshes .....	685
18.6.3	Carbon Sinks .....	686
18.6.4	Decomposition of Surface Peat .....	686
18.6.5	Carbon Losses Resulting from Wetland Deterioration .....	686
18.7	Nitrogen Cycling .....	687
18.7.1	Nitrogen Inputs .....	688
18.7.2	Nitrogen Regeneration and Uptake .....	688
18.7.3	Nitrogen Losses .....	689
18.7.4	Nitrogen Budget.....	690
18.7.5	Processing Capacity of Added Nitrogen Entering Louisiana Wetland.....	691
18.7.6	Capacity of Freshwater Marsh to Process Nitrate in Diverted Mississippi River Water.....	692
18.8	Sulfur Cycling .....	693
18.8.1	Forms of Sulfur in Louisiana Marsh Soil .....	693
18.8.2	Sulfate Reduction Rates in Louisiana Marsh Soils .....	694
18.8.3	Flux of Reduced Sulfur Gases.....	694
18.8.3.1	Salt Marsh .....	696
18.8.3.2	Brackish Marsh .....	696
18.8.3.3	Freshwater Marsh.....	697
18.9	Case Studies of Factors Governing the Fate of Toxic Organic Compounds and Pollutants in the Louisiana Coastal Wetland.....	697
18.9.1	Toxic Organic Compounds.....	697
18.9.2	Mercury .....	700
18.10	Summary .....	701
	Study Questions .....	701
	Further Readings.....	702

<b>Chapter 19</b>	<b>Advances in Biogeochemistry .....</b>	<b>703</b>
19.1	Introduction .....	703
19.2	Biogeochemical Processes .....	705
19.3	Algal and Microbial Interactions .....	708
19.4	Vegetation and Microbial Interactions .....	709
19.5	Modern Tools to Study Biogeochemical Cycles.....	710
19.5.1	Microbial Communities and Diversity .....	710
19.5.2	Nuclear Magnetic Resonance Spectroscopy .....	711
19.5.3	Diffuse Reflectance Spectroscopy .....	711
19.5.4	Stable Isotopes.....	711
19.6	Synthesis: Mechanistic and Statistical Models .....	712
19.6.1	Mechanistic Models .....	712
19.6.2	Stochastic (Statistical) Models .....	713
19.6.3	Geospatial Models.....	715
19.7	Future Directions and Perspectives .....	716
	Further Readings.....	717
	<b>References.....</b>	<b>719</b>
	<b>Index.....</b>	<b>757</b>