contents

preface

Part One **Principles of Marine Science**

viii

3
3
12
11
16
19
21
21
24
35
40
41
43

The Waters of the Ocean Motion in the Ocean Vertical Motion and the Three-Layered Ocean

Boxed Readings	
Tall Ships and Surface Currents	59
Waves That Kill	60
Interactive Exploration	65
Part Two	
Life in the Marine	
Environment	67
4 Some Basics of Biology	69
The Ingredients of Life	69
Living Machinery	74
Challenges of Life in the Sea	77
Perpetuating Life	81
The Diversity of Life in the Sea	84
Boxed Reading	
From Snack to Servant: How Complex Cells Arose	77
Interactive Evaluration	00
	90
5 The Microbial World	91
Prokaryotes	92
Unicellular Algae	96
Protozoans: The Animal-like Protists	100
Fungi	102
Boxed Readings	
Symbiotic Bacteria—The Essential Guests	94
Tiny Cells, Big Surprises	99
The Bay of Fire	100
Interactive Exploration	103

v

6 Multicellular Primary Producers: Segwoods		
and Diants		
and Plants	105	-
Multicellular Algae: The Seaweeds	106	
Flowering Plants	114	
Boxed Reading		
Seaweeds for Gourmets	113	
Interactive Exploration	116	,
7 Marine Animals		
without a Backbone	117	
Sponges	118	
Cnidarians: A Radially Symmetrical		
Body Plan	120	-
Comb Jellies: Radial Symmetry One		
More Time	123	
Bilaterally Symmetrical Worms	124	
Molluscs: The Successful Soft Body	130	
Arthropods: The Armored Achievers	135	-
Lophophorates	139	
Arrow Worms	141	
Echinoderms: Five-Way Symmetry	142	
Hemichordates: A "Missing Link"?	146	
Chordates Without a Backbone	146	
Boxed Readings		
The Case of the Killer Cnidarians	123	
Interactive Exploration	12.5	
	150	
8 Marine Fishes	153	
Vertebrates: An Introduction	154	
Types of Fishes	154	
Biology of Fishes	160	

Boxed Readings	
Shark!	158
A Fish Called <i>Latimeria</i>	170
Interactive Exploration	177
9 Marine Reptiles, Birds,	
and Mammals	179
Marine Reptiles	181
Seabirds	183
Marine Mammals	187
Boxed Readings	
The Endangered Sea Turtles	182
The Whales That Walked to Sea	192
The Other "Big Bang Theory"	200
How Intelligent Are Cetaceans?	203
Interactive Exploration	210
Part Three	
Structure and Function	
of Marina Ecosystems	
OI IVIAI IIIE ECOSYSTEIIIS	213
10 An Introduction to Ecology	213 215
10 An Introduction to Ecology The Organization of Communities	213 215 215
10 An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials	213 215 215 221
10 An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine	213 215 215 215 221
10 An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment	213 215 215 221 221
10 An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment	213 215 215 221 221 229
10 An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Boxed Readings	213 215 215 221 229
 In the Ecosystems In An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Boxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small 	213 215 215 221 229 224 232
 Interaction of Communities The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Boxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small 	213 215 215 221 229 224 232
Of What the Ecosystems It is a second structure of the second structure of th	213 215 215 221 229 224 232 233
 Invarine Ecosystems Invarine Ecosystems Invarine Ecosystems Inviron of Communities The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Ecological Zonation of the Marine Environment Boxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small Interactive Exploration Interactive Exploration 	213 215 215 221 229 224 233 233 235
Of What the Ecosystems It was the Ecosystems It of An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Boxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small Interactive Exploration It Detween the Tides Rocky Shore Communities	213 215 215 221 229 224 233 233 235 236
Of What the Ecosystems It of Number Peopsistems It of An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Nexed Readings Cleaning Associations Biodiversity: All Creatures Great and Small Interactive Exploration It Detween the Tides Rocky Shore Communities Soft-Bottom Intertidal Communities	213 215 215 221 229 224 232 233 235 236 252
 Interaction of Communities The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Boxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small Interactive Exploration It Between the Tides Soft-Bottom Intertidal Communities Soft-Bottom Intertidal Communities 	213 215 215 221 229 224 233 235 236 252
Of What me Ecosystems It of An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Moxed Readings Cleaning Associations Biodiversity: All Creatures Great and Small It creative Exploration It Detween the Tides Soft-Bottom Intertidal Communities Soft-Bottom Intertidal Communities Marked Reading Transplantation, Removal, and Caging	213 215 215 221 229 224 232 233 235 236 252
Of Warme Ecosystems In An Introduction to Ecology The Organization of Communities The Flow of Energy and Materials Ecological Zonation of the Marine Environment Mozed Readings Cleaning Associations Bodiversity: All Creatures Great and Small Interactive Exploration Interactive Exploration Soft-Bottom Intertidal Communities Soft-Bottom Intertidal Communities Margen Reading Transplantation, Removal, and Caging Experiments	213 215 215 221 229 224 233 235 236 252 246

12 Estuaries: Where Rivers Meet the Sea

259

Origins and Types of Estuaries	259
Physical Characteristics of Estuaries	260
Estuaries as Ecosystems	262
Boxed Reading	
Fiddler on the Mud	269
Interactive Exploration	276
13 Life on the Continental Shelf	277
Physical Characteristics of the	
Subtidal Environment	277
The Continental Shelf as an Ecosystem	279
Boxed Readings	
Under the Antarctic Ice	279
Life in Mud and Sand	283
Interactive Exploration	295
14 Coral Reefs	297
The Organisms That Build Reefs	297
Kinds of Coral Reefs	305
The Ecology of Coral Reefs	311
Boxed Readings	
Coral Reproduction	299
"Must Have Been Something I Ate"	319
Interactive Exploration	321
15 Life Near the Surface	323
The Organisms of the Epipelagic	324
Living in the Epipelagic	333
Epipelagic Food Webs	341
Boxed Readings	
Red Tides and Harmful Algal Blooms	326
Swimming Machines	340
TI I TI I	
Interactive Exploration	355

16 The Ocean Depths 357 The Twilight World 359 The World of Perpetual Darkness 367 The Deep-Ocean Floor 371 Hot Springs, Cold Seeps, and Dead Bodies 377 **Boxed Readings Biodiversity in the Deep Sea** 372 The Chambered Nautilus 376 Interactive Exploration 379 Part Four Humans and the Sea 381 17 Resources from the Sea 383 The Living Resources of the Sea 383 Non-Living Resources from the Sea Floor 401 Non-Living Resources from Seawater 403 **Boxed Readings** Of Fish and Seabirds, Fishers and Chickens 393 Take Two Sponges and Call Me in the Morning 401 Interactive Exploration 405 **18** The Impact of Humans on the Marine Environment 407

Modification and Destruction	
of Habitats	407
Pollution	409
Threatened and Endangered Species	419
Conserving and Enhancing	
the Environment	423
Boxed Readings	
Living in a Greenhouse: Our Warming Earth	410

Biological Invasions: The Uninvited Guests

420

Sand on the Run, or What to Do with Our Shrinking Beaches	424	Appendix A	
Five Simple Things You Can Do to Save	121	Units of Measurement	439
the Oceans	426	Appendix B	
Interactive Exploration	427		
		The World Ocean	440
19 The Oceans and		Appendix C	
Human Affairs	429	Major Coastal Communities	
Oceans as Barriers and Avenues	429	of North America	441
Oceans and Cultures	430		
Oceans and Recreation	434	Glossary	443
Prospects for the Future	435	Credits	457
Boyod Dooding		Index	459
Marina Archaeology	499		
Marine Archaeology	433		
Interactive Exploration	437		