



MARINE BIOLOGY

H. V. THURMAN • H. H. WEBBER

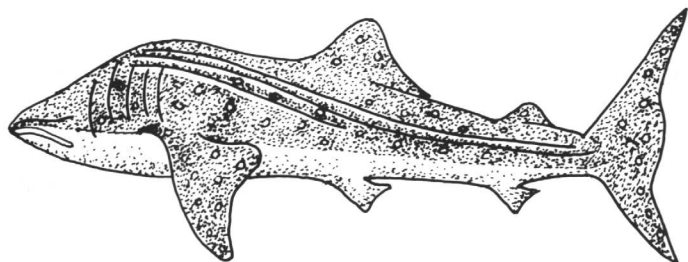
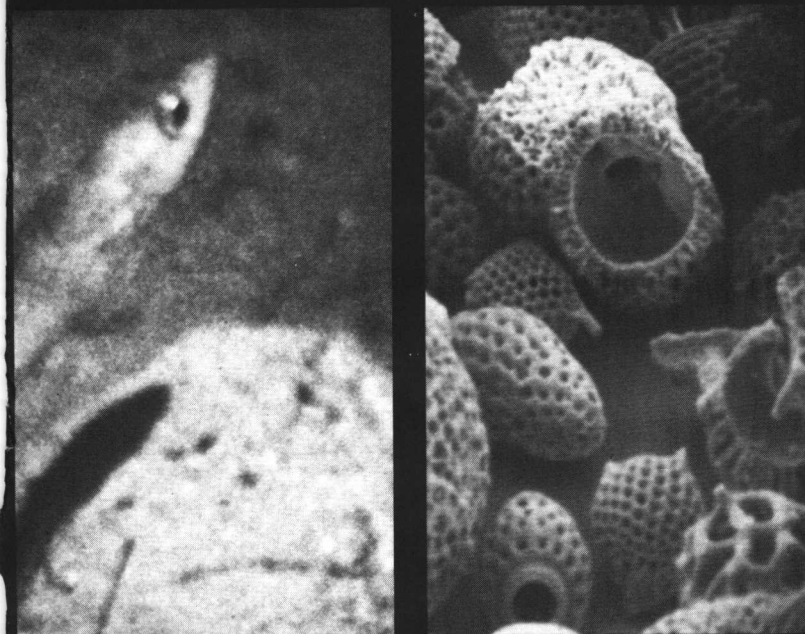
MARINE BIOLOGY

HAROLD V. THURMAN

Mt. San Antonio College

HERBERT H. WEBBER

Western Washington University



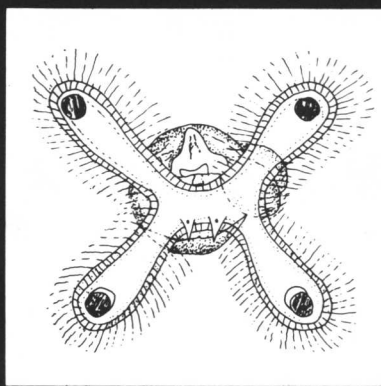
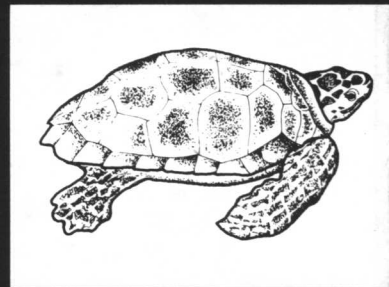
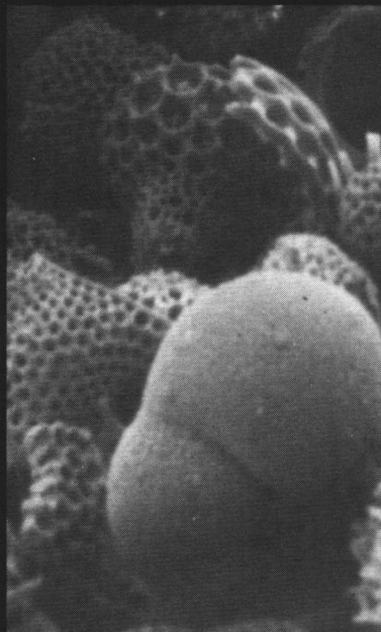
Published by
Charles E. Merrill Publishing Company
A Bell & Howell Company
Columbus, Ohio 43216

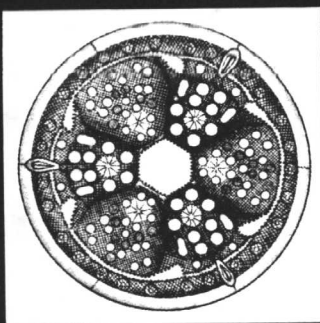
This book was set in Univers and Times Roman.
Cover design: Tony Faiola
Cover photo: David Doubilet
Text design: Cynthia Brunk
Production coordination: Martha Morss

Copyright © 1984 by Bell & Howell Company. All rights reserved.
No part of this book may be reproduced in any form, electronic
or mechanical, including photocopy, recording, or any information
storage and retrieval system, without permission in writing
from the publisher.

Library of Congress Catalog Card Number: 83-062582
International Standard Book Number: 0-675-20139-X
Printed in the United States of America
1 2 3 4 5 6 7—90 89 88 87 86 85 84

Charles E. Merrill Publishing Company
A Bell & Howell Company
Columbus Toronto London Sydney





PREFACE

Historically, marine biology has been taught as an upper division course. It was offered only to students who had taken prerequisite courses that fully prepared them to understand the physical components of the marine environment and the ecology of life in the oceans. In recent years, however, marine biology has been offered as an overview course to meet general education requirements in science. In the latter form, the course cannot hope to achieve the depth of coverage attained in the traditional program. Still, a major objective of the overview course is to help students develop a significant understanding of marine ecology. The fact that marine biology may be the only course in marine science a student will take presents the instructor with a problem. Students may have insufficient knowledge of the physical ocean to appreciate the ecological relationships of organisms to the physical marine environment. This text, therefore, provides an introduction to the physical ocean that will serve as a background and foundation for understanding life in the oceans.

Marine Biology is divided into six parts which will allow instructors to identify the areas that best fit the plan of their courses. Twelve special features interspersed in the text cover topics of current research and especially interesting phenomena in the marine ecosystem. These features will stimulate students and help them appreciate the dynamic nature of the science of marine biology.

Part 1, "An Overview," introduces students to the concepts, problems and techniques of marine biology. Chapter 1, "Marine Biology: Fundamental Concepts," presents biological concepts related to the origin, evolution and classification of organisms. Chapter 2, "Investigating Life in the Ocean," introduces students to the study of marine life with an overview of the history, areas of study and procedures used by marine biologists.

In Chapter 1 the special feature "Did Life Begin on the Ocean Floor?" presents a new hypothesis developed from recent knowledge and illustrates the continuous growth of knowledge in marine biology. The Chapter 2 special feature, "Fishery Assessment with the Free-vehicle Drop Camera," describes the use of underwater photography to assess fisheries, a technique that is in early development as a research tool.

Part 2, "The Physical Ocean," gives the student an opportunity to develop an understanding of the abiotic components of the marine ecosystem—the ocean floor, the properties of water and the ocean's motions (currents, waves and tides). Chapter 3, "The Ocean Floor," provides a minimal survey of the provinces of the ocean bottom, marine sediments and global plate tectonics. If the instructor does not wish to cover Chapter 4, "The Nature of Water," and Chapter 5, "The Nature and Motion of Ocean Water," in depth as a formal part of the class, students can use these chapters as a reference or optional reading to increase their understanding of the physical ocean. Both chapters contain tables emphasizing the important physical phenomena of the oceans and their biological significance. A single one-hour lecture could be organized around these tables to develop students' awareness of physical phenomena and their role in marine ecology.

Three special features in Part 2 will enhance students' understanding of the physical components of the marine environment. "Hydrothermal Vent Biotic Communities" (Chapter 3) and "Gulf Stream Rings and Marine Life" (Chapter 5) present the results of recent and ongoing research. "Grunion and the Tides" (Chapter 5) describes the wondrous relationship between spawning and tidal movements so long observed on California and Baja California beaches.

Part 3, "General Ecology," presents an overview of ecological relationships in the ocean. Chapter 6, "Conditions for Life in the Sea," considers the responses of organisms to physical factors such as salinity, light, nutrient availability, density and viscosity. The chapter concludes with a description of the ecological divisions of the marine environment and its basic populations—plankton, nekton and benthos. Chapter 7, "Biological Productivity and Energy Transfer," continues the ecological discussion of the previous chapter with emphasis on photosynthesis, chemosynthesis and energy flow. Productivity of polar, low-latitude and temperate oceans are compared. Biogeochemical cycling, trophic levels and biomass pyramids are covered, and the chapter concludes with a discussion of the ecology of the Peruvian anchovy fishery.

The special feature in Chapter 6, "Deep-ocean Benthos," is an interview with Dr. Robert R. Hessler on his view of how life evolved on the deep-ocean floor. It can be compared to the hypothesis of Dr. John Corliss presented in the special feature in Chapter 1. "Satellites and Plankton" in Chapter 7 describes the new remote sensing technique that may greatly increase the ability of marine biologists to make synoptic measurements of marine biological productivity.

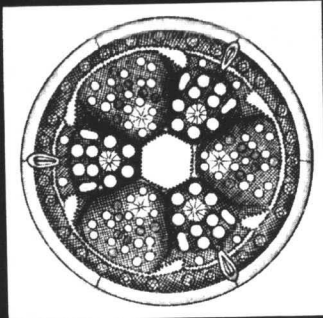
Part 4, "Marine Organisms," organizes and discusses, taxonomically, the major marine populations. Chapter 8, "Monera, Protista, Mycota and Metaphyta," considers the producers and microscopic consumers of the marine environment. Chapter 9, "The Smaller Marine Animals," covers the small invertebrate phyla; and Chapter 10, "The Large Animals," describes the large cephalopods and vertebrates. Although all three chapters are organized taxonomically, they present substantial ecological information on the organisms discussed. The Chapter 10 special feature, "Competitive Release: Whales, Krill and Humans," considers the effects of human intervention on the antarctic food web.

Part 5, "Marine Habitats," divides the marine environment into four habitats—"The Intertidal Zone" (Chapter 11), "Benthos of the Continental Shelf" (Chapter 12), "The Photic Zone" (Chapter 13) and "The Deep Ocean" (Chapter 14). "Inhabitants of the Coral Reef," a special feature in Chapter 12, provides a survey of the populations of one of the ocean's most beautiful environments. "PROBES: Marine Science Steps Forward" (Chapter 12) and "Salmon Ranching: A Pilot Project" (Chapter 13) illustrate the continuing attempts by humans to exploit the biological resources of the oceans.

Part 6, "The Ocean under Stress," offers an overview of some of the current concerns about ocean pollution. Chapter 15, "Marine Pollution," looks at the

meaning of pollution, the capacity of the oceans to absorb human contamination and pollution control in the United States. Pollution sources including petroleum, sewage, radioactive waste, halogenated hydrocarbons and mercury are considered. A critique of the performance of the U.S. Food and Drug Administration in regard to its handling of mercury contamination of fish and a summary of international efforts to combat marine pollution completes the chapter. A special feature, "Subsea Disposal of High-level Nuclear Waste," provides a status report on research being conducted to determine the feasibility of disposing high-level waste beneath the ocean floor.

The authors would like to thank the following reviewers who offered critical comments on the manuscript at various stages: Richard Brusca (University of Southern California), Neil Crenshaw (Indian River Community College), Cynthia Groat (Bowling Green State University), W. K. Patton (Ohio Wesleyan University), Joseph L. Simon (University of South Florida), Robert E. Terwilliger (Oregon Institute of Marine Biology, University of Oregon) and P. Kelly Williams (University of Dayton).



CONTENTS

PART ONE AN OVERVIEW

1 MARINE BIOLOGY: FUNDAMENTAL CONCEPTS 5

- The Origin of Life 5
 - Origin of the Earth 5
 - Life Forms in the Oceans 6
- Evolution 10
- Taxonomy 14
- Did Life Begin on the Ocean Floor?* 11

2 INVESTIGATING LIFE IN THE OCEAN 19

- Early Investigations of the Ocean 19
- The Oceans as Resource 20
- Instruments and Techniques for Investigating the Oceans 23
- Fishery Assessment with the Free-vehicle Drop Camera* 26

PART TWO THE PHYSICAL OCEAN

3 THE OCEAN FLOOR 37

- Landforms on the Ocean Floor 37
 - Continental Margin 37
 - Deep-ocean Basin 38

Ocean Sediments	40
Global Plate Tectonics	41
Laurasia and Gondwanaland	43
The Spreading Mechanism	44
Spreading-center Biocommunities	47
<i>Hydrothermal Vent Biotic Communities</i>	50

4 THE NATURE OF WATER 59

Solvent Properties of Water	59
Thermal Properties of Water	60
Freezing and Boiling Points of Water	60
Heat Capacity	61
Surface Tension	63
Water Density	64

5 THE NATURE AND MOTION OF OCEAN WATER 69

Salinity	69
Solar Radiation	70
Distribution of Light	70
Density Stratification	71
Sound Transmission	72
Currents	75
Horizontal Circulation	75
Vertical Circulation	82
Waves	82
Wind-generated Waves	82
Tides	85
<i>Gulf Stream Rings and Marine Life</i>	79
<i>Grunion and the Tides</i>	88

PART THREE GENERAL ECOLOGY

6 CONDITIONS FOR LIFE IN THE SEA 101

General Conditions	101
Effects of Salinity	102
Availability of Nutrients	104
Size and Support	107
Viscosity	108
Temperature	108
Divisions of the Marine Environment	109
Pelagic Environment	110
Benthic Environment	112

Distribution of Life in the Oceans	112
Plankton	116
Nekton	117
Benthos	118
<i>Deep-ocean Benthos</i>	113

7 BIOLOGICAL PRODUCTIVITY AND ENERGY TRANSFER 123

Primary Productivity	123
Distribution of Productivity	124
Temperature Stratification and Nutrient Supply	124
Chemosynthetic Productivity	131
Energy Transfer in the Marine Ecosystem	132
Energy Flow	132
Biogeochemical Cycling	133
Trophic Levels and Biomass Pyramids	135
A Case Study in Biological Productivity	138
<i>Satellites and Plankton</i>	125

PART FOUR MARINE ORGANISMS

8 MONERA, PROTISTA, MYCOTA AND METAPHYTA 147

The Monera	147
Bacteria	147
Blue-green Algae	148
The Protists	149
Dinoflagellates	149
Diatoms, Silicoflagellates and Coccolithophores	150
Protozoa	153
Green Algae	154
Brown Algae	158
Red Algae	159
The Fungi	160
Angiosperms	161

9 THE SMALLER MARINE ANIMALS 167

Metazoan Phylogeny	168
The Sponges	170
The Radiate Animals	174
The Cnidarians	174
The Ctenophorans	181
The Lower Bilateral Animals	183
The Platyhelminthes	183
The Nemertean	185

The Aschelminthes	187
The Protostomes	188
The Molluscs	188
The Annelids	194
The Arthropods	198
Minor Protostomes	207
The Deuterostomes	209
The Echinoderms	209
The Chordates (Tunicates)	213
Minor Deuterostomes	214
The Lophophorates	215

10 THE LARGE ANIMALS 221

Cephalopods	222
Reptiles	224
Fish	227
Sharks and Rays	228
Teleost (Bony) Fish	228
Swimming	232
Buoyancy	236
Food and Feeding	237
Senses	238
Migrations and Schooling	238
Reproduction	241
The Seabirds	242
Tubenoses	242
Pelicans and Related Types	243
The Gull Group	244
Penguins	245
Food and Feeding	245
Migrations and Foraging	247
Reproduction	250
Marine Mammals	251
Swimming and Diving	254
Food and Feeding	256
Migrations	262
Reproduction	263
Senses and Intelligence	263
Pinnipeds	265
<i>Competitive Release: Whales, Krill and Humans</i>	258

PART FIVE MARINE HABITATS

11 THE INTERTIDAL ZONE 275

The Nature of the Intertidal Zone	275
Rocky Shores	279

The Littoral Fringe	280
The Eulittoral Zone	282
The Sublittoral Fringe	284
Intertidal Rock Pools	284
Adaptations of Intertidal Flora and Fauna	285
Food Habits in the Rocky Intertidal	286
Other Influences on Distribution	287
Particulate Shores	288
Exposed Sandy Beaches	290
Mud Flats	293

12 BENTHOS OF THE CONTINENTAL SHELF 303

Coral Reefs	303
Reef Formation	306
Corals as Food	311
Seagrass Meadows	312
Kelp Forests and Seaweed Beds	319
Soft Sediments	320
Infauna and Epifauna	322
Food Sources	324
<i>Inhabitants of the Coral Reef</i>	307
<i>PROBES: Marine Science Steps Forward</i>	314

13 THE PHOTIC ZONE 329

Divisions of the Photic Zone	329
The Air-Water Interface	330
Subtropical Gyres	330
Upwelling Area	331
The Neritic Zone	332
Organisms of the Photic Zone	332
The Phytoplankton	332
The Zooplankton	333
The Holoplankton	334
The Meroplankton	337
Feeding and Food Webs	340
Patchiness	344
Horizontal Patchiness	344
Seasonal Patchiness	345
Vertical Patchiness	346
Adaptations to the Pelagic Environment	348
Buoyancy	348
Swimming	349
Color	349
Vertical Migrations	350
Bioluminescence	351
<i>Salmon Ranching: A Pilot Project</i>	341

14 THE DEEP OCEAN 357

Divisions of the Deep-sea Environment	360
Organisms of the Deep Ocean	361
Zooplankton	361
Nekton	362
Benthos	364
Adaptations to the Deep-sea Environment	370
Morphological Adaptations	371
Bioluminescence	372
Sound and Smell	372
Reproduction	372
Hydrostatic Pressure	373
Buoyancy	374
Feeding and Food Webs	374
Special Communities in the Deep Ocean	376
Benthos of Deep-sea Trenches	377
Hydrothermal Vent Communities	378

PART SIX THE OCEAN UNDER STRESS

15 MARINE POLLUTION 385

The Ocean's Tolerance for Pollution	385
Marine Pollution Control in the United States	387
Major Sources of Pollution	388
Petroleum	388
Sewage	392
Radioactive Waste	394
DDT and PCBs	399
Mercury: A Case Study	399
International Efforts to Protect the Marine Environment	402
<i>Subsea Disposal of High-level Nuclear Waste</i>	395

APPENDIX A	
The Metric System and Conversion Factors	407

APPENDIX B	
Prefixes and Suffixes	409

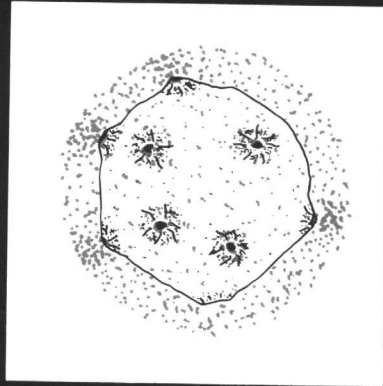
APPENDIX C	
Taxonomic Classification of Common Marine Organisms	413

GLOSSARY	417
-----------------	------------

INDEX	437
--------------	------------

MARINE BIOLOGY

PART ONE



AN OVERVIEW

