Welcome to the fourth edition of *Marine Biology: Function, Biodiversity, Ecology*. This new edition reflects my continued excitement at the teaching of marine biology, a far-reaching science that manages to excite a broad spectrum of students. We marine biologists are lucky to have exciting creatures, great adventures, and continuing discoveries that manage to enchant students. The challenge in a text is to inject this excitement into an organized approach to the subject. Many students find marine biology a little daunting. No surprise to me, because it is daunting to put it all into a text. I believe, though, that every student can acquire the broad spectrum of biological knowledge included in marine biology while appreciating the organismal diversity of the marine realm. To make that possible, students must learn concepts along with the facts and begin to think and reason like scientists. Just as important, they must feel the pulse of current happenings.

The goal of this text is to appeal to a wide range of students, while also preparing future specialists with the knowledge and tools needed to conduct their research. Marine biology is such a diverse subject that principles must guide our understanding. I firmly believe that, without principles and a sense of excitement, students will see only an accumulation of facts. They will fail to see how the same basic processes operate in vastly different marine communities.

That is why the text addresses three major process-driven themes: functional biology, ecological processes, and biodiversity. It is why the text uses full color throughout in drawings that depict marine biological processes and a large number of photographs to connect students with marine environments and organisms. It is also why I have paid much attention to recent research developments and have included a series of essays, called “Hot Topics in Marine Biology.” These features will put students in contact with the current world of exciting research. In both the text and the Hot Topics, I try to connect the students to some of the most important recent research with an extensive literature section that is now online so that students can get to the best work for term papers and projects without too much distraction in the text. In my own classes I point out that a good teacher shows students the way to good science because library databases are not user friendly where finding excellent science research is concerned.

**The Philosophy of This Text**

This text is designed for a one-semester course at the sophomore to senior level. Some students will have already taken a college-level biology course with coverage of organismal diversity, and they will benefit greatly. A small number may even have taken a course in marine invertebrates or vertebrates and an introductory course in oceanography. That said, I have successfully taught from this text for many years, and many students had no background in organismal biology or ecology. If the book is supplemented with journal articles, it can also be used in a more advanced undergraduate course in marine ecology. The new edition contains many updated references to the primary literature, which are expanded and now online with a simple link from the text chapters. This is a valuable resource to get students started on term papers and essays. The Marine Biology Web Page (www.oup.com/us/levinton), which I founded a number of years ago, links students to many more views of marine biology and to a greater diversity of organisms. It is a continuing objective to merge principles with an appreciation of organismal diversity in the ocean.

I have taught Marine Biology for over 30 years and have always been amazed at the diversity of students who take the course. Biology majors, marine science majors, geology majors, and even some humanities majors sit side by side. At my university, marine science has become a separate undergraduate discipline in recent years, and these students have truly learned the interdisciplinary nature of marine biology. All learn a great deal, and all seem to come away with a love for the ocean. You don’t have to convince them to be there: They want to learn about marine biology.

I do my best to keep that interest alive, and I find that field trips and the use of color photographs and other illustrations throughout the text help a great deal. So do the online resources accompanying this text. *Marine Biology Explorations* includes hundreds of photographs from habitats discussed in the text and still more. As mentioned, an expanded and updated reference list is also online. In class, I keep a large map of the oceans on the wall for the geographic context of our discussions. I have taken many of my students with me to marine labs, and they have launched careers in science or used their backgrounds to enter other areas. I hope the text will help a wider audience to get excited about marine life. I hope,
too, that they will understand how the ocean works and why our marine realm is so threatened.

**A Principles-Driven Approach**

Marine biology applies the principles of ecology and evolution, using the crucial tools of cell biology, biomechanics, and molecular biology to a wide range of marine biological studies. These fields of study and their interactions govern the text’s three overarching themes: functional biology, biodiversity, and ecological processes.

Function refers to the way organisms solve problems and how physical and chemical factors constrain and select the solutions. What shape should a maneuvering fish have, relative to a continuously swimming fish? How does a small peptide manage to be such an effective poison when injected by a snail into a prey? How does this specific biochemical adaptation feed into an understanding of biodiversity? I believe this textbook is unique in combining effectively functional biology with ecological thinking.

Biodiversity is an essential part of marine biology, and I introduce the topic both through introductions to the principles used to study and explain biodiversity and to the factors that strongly affect marine biodiversity. A separate chapter discusses diversity and the processes that regulate it, both ecological and evolutionary. It is crucial that the student see the historical roots of many current distributions, which are affected by processes ranging from plate tectonics to climate change. This edition adds a great deal of coverage of recent advances, including molecular tools used to identify microbial organisms and activity in the plankton and molecular methods used to study dispersal, speciation, and the rise of marine adaptations. A chapter devoted to biodiversity makes the connections between evolutionary process, biodiversity, and biogeography. These areas are related directly to issues of marine conservation.

Last, ecology examines the interactions of organisms with their environment. Ecology tries to understand the distribution and abundance of organisms. It involves a series of processes, which I introduce in the context of a hierarchy—from *individual populations* to *ecosystems*. It also involves a discussion of important ecological processes along with accounts of major marine habitats and communities. This edition pays special attention to modern concepts of populations and species interactions, including connectivity, metapopulations, regional genetic differentiation, large-scale control of dispersal, biological invasions, and alternative stable states of communities. My background in geology, ecology, and evolutionary biology allows me to frequently combine ecological and evolutionary thinking in discussing marine biology problems.

**Organization**

We begin with a brief historical background. Marine biology has a history that is worth understanding, but it is also crucial to introduce the student to how science works. Chapter 1 therefore discusses framing and testing hypotheses, as well as making tests practical enough that they can be put to direct use. From the very beginning, I introduce the student not only to the scientific method, but also to how it translates into an intellectual tool with real-world applications.

Chapters 1 through 6 introduce basic principles of how the ocean works in a physical, chemical, and ecological context and how marine organisms function with these constraints. The second chapter gives the student a comprehensive introduction to oceanography and the important properties of sea water that might affect marine organisms. I work in climate change at this stage because it will be part and parcel of many discussions throughout the text. This edition greatly expands the effects of temperature and especially ocean acidification, and the student sees how an understanding of the ocean and sea water properties will directly affect the fate of marine organisms in the future. I then introduce ecological principles so that students can work their way through concepts using marine examples. This allows all students to be brought up to a level of ecological thinking and an understanding of oceanographic processes. They will see this “big picture” as they read the rest of the text. A crucial chapter then introduces students to how the physics of fluids shapes the constraints and adaptations of marine organisms. As far as I know, this crucial subject is missing in all other marine biology texts, and allows a connection to a complete understanding of how the marine organisms function in the rather complex fluid environment. These chapters conclude with a comprehensive introduction to reproductive strategies, larval dispersal, and migration, which sets up the big picture of the geographical distribution of marine species, down to the microscale of how mobile marine larvae succeed in finding a place to live in a turbulent and stressful world.

Chapters 7 through 10 cover the *organisms* and *processes* important in the open sea. This two-step approach is essential so that students will understand the overall economy of the marine realm. Chapter 10 uses a global-scale approach to show how biological studies of the ocean lead to an understanding of the world’s potential for fisheries and the global biological impact on the ocean of climate change. Processes in the water column are also crucial in Chapters 11 through 15 for understanding the benthos, which depends both directly and indirectly on the water world above. In Chapters 11 and 12 I cover benthic creatures and then go on to discuss the principles necessary to understand the biology of marine bottom organisms (Chapter 13) and the major nearshore marine bottom habitats (Chapters 14–16). By necessity, I have been selective. I emphasize those habitats that are not only important and interesting, but also where important principles can be illustrated to their best advantage. Community-level interactions are emphasized, as is global climate change as it relates to major changes in habitats such as coral reefs. I discuss a range of geographic locations so that the instructor will find local examples in many instances. Crucial habitats such as the intertidal, seagrasses, coral
reefs, mangroves, estuaries, salt marshes, kelp forests, and others are discussed both from the points of habitat distinctions and ecological processes and the impacts of biological invasions and climate change. I have added a new section on oyster reefs because of their great worldwide importance as foci for biodiversity and their role in ecosystem services.

Chapter 16 then looks at the important gradient from the continental shelf to the deep sea, paying special attention to some of the fascinating discoveries about biological function and fascinating habitats, from hot vents to deep water coral mounds to the newly discovered subsurface bacterial realm over 500 m beneath the sea floor. I have greatly expanded coverage of Arctic and Antarctic environments. The Antarctic is center stage in our focus on the current and future impacts of climate change, and the text incorporates a wide range of discussions from the organismal to the ecosystem level. Chapter 17, on gradients in biodiversity, sums up larger-scale variants in the sea and includes sections on invasive species, conservation of biodiversity, and conservation genetics. More and more, students and researchers have focused their attention to the deteriorating conditions of the ocean, and conservation is a major field of emphasis.

Finally, Chapters 18 and 19 tackle other human interactions with the sea, as both a source of food and, unfortunately, a waste receptacle. I cover human effects on the ocean. Throughout the text, the effects of climate change are brought up in many contexts, and how those effects are related to chemical issues such as acidification and facilitation of biological invasions. I also place strong emphasis on the reorganization of communities that has been initiated by the interaction of human activities and strong ecological interactions found in natural communities and in food webs. The impact of overfishing on populations and trophic cascades is a crucial part of a complete chapter on fisheries and mariculture. The role of toxic substances, eutrophication, and hypoxia are discussed clearly and in depth. I have added to Chapter 18 a section on drug discovery in the ocean, because of the great student interest in this subject and the connections between biodiversity and the new sources of compounds to combat pain and disease, such as cancer.

A Refined Learning Package

This text has a series of pedagogical features designed to help students absorb a great variety of information by engaging their imaginations, helping them organize and prioritize important principles, and keeping them focused on the big without getting lost in the details.

“Hot Topics in Marine Biology” essays throughout the text introduce students to recent advances in the understanding of marine biology and discuss current issues, especially marine–biological debates and discoveries. Instructors can use these essays to kick off discussion, to expand a student’s horizons, for course assignments, or as topics for term papers. Reorganizations of communities from the Antarctic to the Gulf of Maine are related to climate change, overfishing, and other processes that are now actively being investigated. A new section on the amazing discoveries of long-distance migration paths through the Pacific Ocean has been added to Chapter 6. I have also tried to give some additional understanding of some current problems by adding a Hot Topics feature that addresses exciting new molecular techniques used to understand marine mammal population structure (Chapter 8), the vexing mortality of marine mammals on the Pacific Coast (Chapter 9), the major issue of management of fisheries (Chapter 18), and what the recent horrific Gulf Oil Spill might tell us about natural processes and oil degradation (Chapter 19). Some Hot Topics have been retained because they are still “hot,” such as the discussion of climate change in the Antarctic Ocean and the impacts on penguin species in Antarctica.

**Key Concept** full-sentence summary statements begin nearly every section of the text to help students identify central points of discussion and to foreshadow what’s to come. These headings allow students to discern the forest from the trees and to see the basic progression of material.

Each chapter ends with a bulleted **Chapter Summary** and a variety of **Thought Questions**. Instructors and students can use these to follow up on important issues in marine biology. The combination of these features and the “Key Concept” heading sentences successfully guides the student through a complex subject.

“Going Deeper” boxes explain equations and related concepts in marine biology. Especially in early chapters, they will help students learn often-difficult material or refresh their memory of elementary courses (e.g., DNA and photosynthesis). They also allow instructors who chose to omit them to press on with no interruptions. An example is the discussion of Leslie Matrices in Chapter 18, which give the student an idea of how age-structured population models help to understand impacts of various factors on fisheries and management decisions.

Extensive **References** lists of classic and contemporary scholarship that instructors may assign as reading and that can lead students to further assignments are linked online from the text. These help students see that marine biology is a living field of research, not just a static textbook of “known” facts, without interrupting the flow of the text.

A comprehensive **Glossary** of marine biology at the end of the text provides students access to a quick definition of important concepts, processes, and terms. A **list of journals** is a resource for students in writing term papers and for further research.

**What Is New and Noteworthy in the Fourth Edition?**

**Expanded illustration program.** We continue the fourth edition using a rich color presentation in order to better demonstrate marine biological principles and introduce organismal diversity in a vivid and captivating visual presentation. The new edition includes over 50 new photos and line drawings (many of the photos generously contributed...
by colleagues), and I believe students will benefit greatly from now having the color photos integrated directly into the relevant textual discussion at hand.

**More applications.** To engage students with the diversity of marine biology today and to highlight the real-world applications of what they are learning, I’ve written many new in-text examples, including seven new Hot Topics in Marine Biology. Students will see the molecular tools can be used to study mating success, how a large-scale program of fish tagging has established major migration routes in the North Pacific Ocean, how a mysterious series of deaths of marine mammals in California was linked to a toxic species of diatom, how fishing management practice can have strong effects on the structure of marine ecosystems, and how microbial degradation may be responsible for a rapid degradation of some components of hydrocarbons following the disastrous Gulf Oil Spill of 2010.

**Current and expanded topics** maintain the excitement that underlies my philosophy of teaching and have been carefully selected to bring the text up-to-date while still remaining focused on the most important principles students need to learn.

- **Ecological interactions.** Strong attention is paid to major ecological interactions that are relevant to ecosystem structure, such as trophic cascades (Chapters 15 and 18), ecological reorganization in New England and elsewhere (Chapter 15), molecular approaches to ecology and evolution (Chapters 7, 8, 13, and 14), natural and human-induced phase shifts (Chapters 14 and 15), biological invasions (Chapters 14, 15, and 17), and climate change (Chapters 4, 8, and 15).

- **Evidence and effects of climate change.** I have greatly expanded coverage of climate change, with attention paid to temperature change in the global ocean and in coastal areas (Chapter 2); the ocean acidification (Chapters 2, 10 and 15); the role of climate change in changing species distributions, facilitating biological invasions, and causing thermal stress (Chapters 2, 4, 14, and 15); and other topics.

- **Methods of environmental assessment, from remote sensing to the molecular level.** I have also expanded coverage of the latest methods for remote sensing, estimating world productivity, and assessing the stress on and change of ecosystems, including satellite methods and ocean observatories (Chapters 1 and 10), genetic and molecular studies of population differentiation (Chapters 3, 6, 17, and 18), the shifting baseline concept (Chapter 18), diversity gradients and the tropical origins of biodiversity (Chapter 17), and molecular methods to trace biological invasions (Chapters 14 and 17).

- **Human impact on biodiversity.** This edition expands coverage of the decline of coral reefs and adds insights on other biological impact such as the increase of sponges at the expense of corals (Chapter 15), overfishing and the issue of relating management decisions to management of the basis of ecosystem function (Chapters 15 and 18), more on declines of sharks and other apex predators (Chapter 18), and the effects of pollution, especially with coverage of the Deepwater Horizon well blowout (Chapter 19).

- **Drug discovery.** I have added a section on the use of marine natural products in the development of drugs.

**Supplements**


- **Companion Website:** Maintained by the author, this Companion Website ([www.oup.com/us/levinton](http://www.oup.com/us/levinton)) provides a multitude of resources for both students and instructors.

  - **Student Resources**
    - *Marine Biology Explorations.* Explore the ocean’s biodiversity through interactive exercises that will take you through nine different marine habitats; including over 450 photos with annotations!
    - Extensive web links to marine biology topics and research literature. You will also find information on careers in marine biology and worldwide marine laboratories.

- **Instructor Resources** (available to adopters of the text and password-protected)

  - **Electronic Images.** All illustrations from the text available in electronic format for download for lecture presentations.
  - **PowerPoint Lecture Notes.** Over 400 lecture notes slides organized by chapter.
  - **Test Bank.** This comprehensive resource includes approximately 400 questions written by the author himself in editable Word files for easy customization (available only on Instructor’s Resource CD-ROM: contact your Oxford University Press sales representative for details).

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Jeffrey Levinton
Stony Brook University, Stony Brook, New York