Laboratory and Field Investigations in

Marine Biology

Sumich/Dudley

Fifth Edition

WCB McGraw-Hill

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Some of the laboratory experiments included in this text may be hazardous if materials are handled improperly or if procedures are conducted incorrectly. Safety precautions are necessary when you are working with chemicals, glass test tubes, hot water baths, sharp instruments, and the like, or for any procedures that generally require caution. Your school may have set regulations regarding safety procedures that your instructor will explain to you. Should you have any problems with materials or procedures, please ask your instructor for help.

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Laboratory and Field Investigations in Marine Biology

Preface

These laboratory and field investigations have been designed for the laboratory portion of an introductory course in marine biology for first- or second-year college students. No previous background in marine biology is assumed; however, some exposure to the basic concepts of biology would be helpful.

This manual was written as the laboratory companion to *An Introduction to the Biology of Marine Life* by James L. Sumich. For this reason, the topic sequence of this manual has been changed in this edition to closely parallel that of the fifth edition text. Both were written for a one-semester course. Each exercise is designed for approximately a three-hour laboratory period. Suggested topics for additional investigation are included. These provide flexibility for the instructors in their choice of topics and allow students to pursue particular interests of their own.

We have attempted to encourage topic and sequence flexibility by avoiding a dogmatic adherence to any one of several appropriate approaches to the study of marine life. Included is a reasonably balanced offering of anatomical, physiological, taxonomic, and ecological studies. We have left to each instructor who uses this manual the opportunity to apply and adapt the experimental methods developed here to specific organisms and habitats that are available and appropriate to their instructional programs. Field study schedules are often dependent on weather, tidal conditions, and other variables. Therefore, the field studies are grouped at the end of this manual.

The variety of laboratory equipment or field sampling gear that may be employed at different institutions is extensive, and specific instructions for their operation have been left to the laboratory instructor. With few exceptions, the organisms used in the exercises and field studies are locally abundant in intertidal areas or are available from several biological supply firms. The equipment is also generally available in most biological laboratories.

The widespread and positive reception of the previous editions of this text continues to be encouraging. This edition represents a continuing effort to better meet the needs of those who use the text. Many suggestions and comments from readers have been considered in the changes that were made. A new exercise on lower invertebrate phyla has been added, and most other exercises have been modified or expanded. Several of the existing illustrations have been revised, and numerous new ones have been added; a two-color presentation aids comprehension. An appendix listing local and regional field guides has also been included.

We wish to thank the many individuals who aided and encouraged the development of this material. Much of the material presented here has been freely borrowed from other disciplines of biology and adapted to fit the needs and limitations of an introductory course. The staff and students of the Department of Biology at Grossmont College suggested numerous improvements and changes during the more than two decades that we have taught this course, and provided useful criticism. We would like to thank the reviewers of this edition: Dennis L. Kelly (Orange Coast College) and Gregory B. Smith (Edison Community College). Unless otherwise credited, the photographs are the authors'.

J.L.S.
G.H.D.

General Introduction

Laboratory and field experiences are an essential part of most science courses and are especially important to the study of marine organisms. The laboratory provides a valuable opportunity to examine in more detail some of the many types of marine organisms to which you may have been briefly introduced through lecture or textual material, and to apply experimental methods to questions about marine organisms.

The exercises in this manual are designed to encourage you to develop your own powers of accurate, critical observation and analysis. There is no equivalent for your own work in the laboratory. Your instructor will provide a laboratory schedule for the semester. Use it to determine the material to be covered, then read that material prior to your laboratory period. Your time in the laboratory is limited; if you leave the laboratory early or fail to come, you will miss something very worthwhile.

Contents

Exercise 1

Asking Questions

Introduction

Science and, in a more restricted sense, biology has a double role in our culture. It is both a body of accumulated information regarding our physical world and its inhabitants, and it is a way of thinking about that world and those inhabitants. Ideally, science should provide us with the information and the processes to achieve a better understanding of the universe in which we live. Modern science has its roots firmly anchored in two fundamental and critical assumptions. The first is that our universe is knowable and explainable. In other words, if we possess adequate information, we can understand and explain how our universe or its parts operate. The second assumption is that such understanding cannot be based on supernatural explanations, but instead must be derived from human perceptions or testable extensions of those perceptions.

An important aspect of any scientific discipline is the search for answers to properly formulated questions. In this class, questions will center on the structures and related functions of marine organisms and how these organisms relate to each other and to the remainder of their environment. Many such questions are provided throughout this text, but you are encouraged to expand on these, pose questions of your own, and strive to answer them. Become inquisitive—question the world you are experiencing. If you do this, rather than just passively accepting information provided by others, you will benefit much more from these laboratory experiences.

In this laboratory exercise, you will have an opportunity to examine the structure of questions, to consider how questions in biology are answered, and finally to ask and evaluate some questions of your own.

I. Some Types of Questions

Below are several yes-or-no questions that differ in their structure and in the kinds of answers you can provide. Take a few minutes to answer each question in the left column. Then, if you are working with a lab group, discuss each question as a group and record your group's consensus answer in the next column.

Your Answer	Group Answer	
______	______	1. Do all species of salmon spawn in streams and lakes?
______	______	2. Is the earth's atmosphere mostly oxygen?
______	______	3. Is the worldwide contribution of marine food to total human food consumption greater than 5%?
______	______	4. Must all sharks continually swim to force water over their gills?
______	______	5. Does the heartbeat rate of a clam increase with increasing water temperature?
______	______	6. Does more plant production occur each year in the ocean than on land?
______	______	7. Is a meter longer than a yard?
______	______	8. Does warm water contain more dissolved oxygen than cold water?
______	______	9. Do baleen whales commonly feed on phytoplankton?
______	______	10. Is it safe to eat fish caught just offshore from a nuclear generating plant?

Now group the questions by the following criteria.

1. Which question(s) are answerable by the definition of a term?

2. Which question(s) cannot be answered or are confusing unless one or more terms are first provided with operational definitions?

3. Which question(s) require you to make a value judgment before answering?

4. Which question(s) are presently unanswerable by you, but appear to be answerable through some type of practical investigation?

II. Approaches to Problem Solving

Your perception of the world is shaped by your past experiences and biases. You may find that some of those experiences and biases will be in direct conflict with information and concepts presented in this course. Resolving those conflicts and understanding how science actually operates will require a variety of critical thinking skills. Some important critical thinking skills include

1. Identifying central issues
2. Distinguishing fact from opinion
3. Evaluating questions
4. Relating causes to effects
5. Recognizing underlying assumptions
6. Recognizing cliches and stereotypes
7. Distinguishing between relevant and irrelevant information
8. Recognizing bias
9. Recognizing the reliability and adequacy of data
10. Drawing justifiable conclusions
11. Determining the validity of an argument
12. Classifying items according to rational criteria
13. Applying appropriate conclusions to new contexts
14. Reasoning from observation to explanation
15. Distinguishing belief from knowledge

These skills are not unique to science but are common to problem-solving approaches in many human activities. Investigations in science rely on some slightly formalized methods of trial and error, using the kinds of skills listed above, to solve problems. Although we often speak of the scientific method, many methods are used in science to solve problems. In a functional sense, investigations into the workings of biological systems usually fall into one of two general categories: descriptive and experimental. Both are useful, and you will encounter examples of both throughout this manual. Each investigative approach begins with a question to which an answer is sought. After that, though, the two approaches used to develop answers to the questions become quite different. Each of these approaches will be described briefly here. In the next section of this exercise, you will have an opportunity for some hands-on experience with these approaches.

A. The Experimental Approach

This approach is employed to answer questions of this sort: What will happen to organism Y if condition X is modified in a deliberate and controlled manner? The experimental approach generally assumes the following format.

1. First, a specific **question** is formulated regarding the organism or system being studied.
2. Then a **hypothesis** is developed as a preliminary, tentative answer to the question based on the information available at the time. In no information is available, the hypothesis is often little more than your best guess. But be careful about becoming enamored with your hypothesis. You must be ready to discard or modify it as new information is obtained.
3. Next, an **experimental procedure** is devised. This consists of the procedural steps you intend to use to test the validity of the hypothesis.
4. The process of running the procedure will provide some experimental **results,** usually some type of data that may need further treatment to improve its usefulness. For some common methods of treating experimental data, see Appendix E.
5. From your experimental results, some **conclusions** may be drawn. These conclusions should either support or reject your stated hypothesis, providing at least a partial answer to the question that initiated this process. The conclusions derived from a single experimental procedure may deny, but can never absolutely prove, the hypothesis. This is the principal reason why conclusions in science must remain tentative and are subject to being modified as additional information becomes available.

B. The Descriptive Approach

Here, questions dealing with attributes are typical, such as: What color is it? or How many are there?

1. Again, the process is initiated with a specific **question** to be answered.
2. However, it is pointless to attempt tentative answers, or hypotheses, to this type of question. Instead the question leads directly to the **procedure.** As before, the procedure includes a list of steps, this time to provide a direct answer to the question.
3. **Results** are gathered, summarized, and treated as in the experimental approach.
4. From the results, a description of the system being questioned is created. As there is no hypothesis, there can be no hypothesis testing. This approach essentially concludes with a "This is the way it is" statement. Experimental and descriptive approaches to problem solving are summarized in figure 1.1.

III. Some Practice in Problem Solving

A. Seawater pH—An Experimental Approach

Acid rain recently has become a critical problem in some parts of the world. Is this a serious problem for marine ecosystems? This exercise poses a specific problem related to the issue of acid rain and outlines an experimental procedure.

Background Information

The **pH** of a solution is a measure of its hydrogen ion (H^+) concentration. Values on the pH scale range from 0 to 14 (fig 1.2). A value of 7 on the pH scale indicates neutral pH, a solution that contains an equal number of hydrogen and hydroxide ions. A solution with a value of less than 7 is considered acidic and represents a high H^+ concentration. Conversely, a solution that has a value greater than 7 is basic, or alkaline, and has a low H^+ concentration.

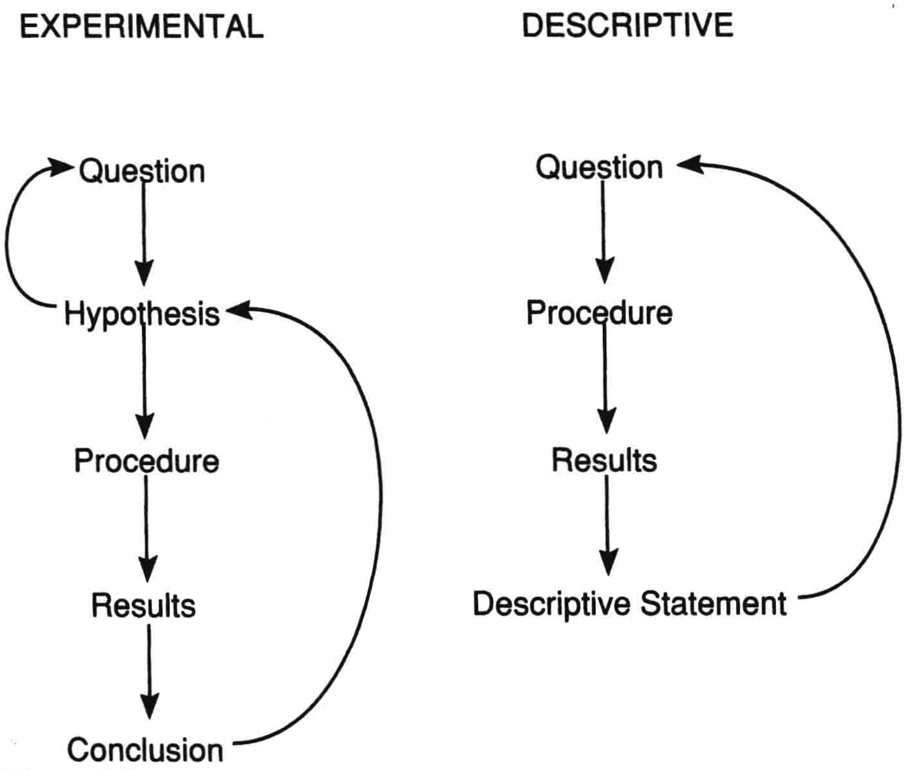

Figure 1.1 A summary comparison of the two problem-solving approaches.

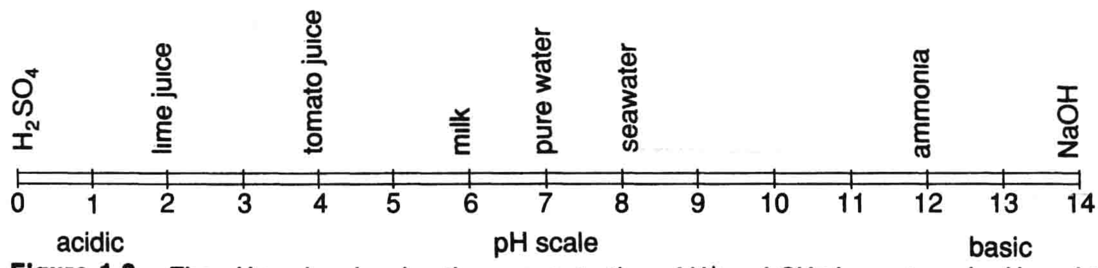

Figure 1.2 The pH scale, showing the concentration of H^+ and OH^- ions at each pH, and typical range of open ocean seawater. Note that the concentration scale is exponential.

Question:

Is seawater more sensitive to pH stresses than fresh water?

This stated problem defines the theme of your investigation. The next step, before proceeding with attempts to solve your group's problem, is to develop a hypothesis. The hypothesis is a suggested possible solution to the problem. The purpose of the hypothesis is to serve as a testable solution to the stated problem. The investigation of the problem should be directed to either confirm or deny the validity of the hypothesis. Write your hypothesis below.

Hypothesis:

The procedure is the approach you intend to employ to test the hypothesis and obtain a solution to the problem. Now your group is ready to actually initiate your investigation of the problem. Follow the procedure given below and record your results in the table provided.

Procedure: pH Sampling
Variations of seawater pH can easily be studied using an electronic pH meter. This instrument is convenient to use and rapidly provides accurate results. The operation of this instrument will be discussed by the instructor. When you are sufficiently acquainted with the methods of operating the pH meter, use it in the following procedure:

1. Place 100 ml of seawater in a 150 ml beaker. Following the directions provided by the instructor and the operating manual for the meter, determine the pH of the sample. Record the pH in the table below.
2. Now add two drops of 0.1 M HCl (hydrochloric acid) to the sample, stir, and record the pH.
3. Continue adding HCl in two-drop increments. Record in table 1.1 the pH of the sample after each two-drop acid addition.
4. Repeat steps 1–3 using distilled water in place of seawater.

Results

Table 1.1 pH of Seawater and Distilled Water Samples with the Addition of Acid

Drops of 0.1 M HCl		0	2	4	6	8	10	12	14
pH	Seawater								
	Distilled Water								

Conclusions
Using the data in table 1.1, draw two curves on the graph in figure 1.3, one for distilled water and one for seawater. Label each curve.

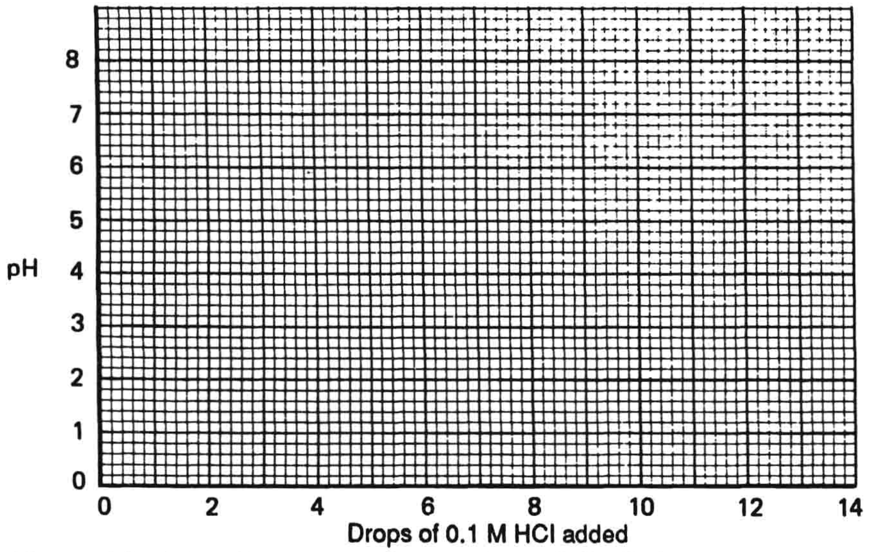

Figure 1.3 The pH changes of seawater and distilled water samples as acid is added.

Which water sample best resisted pH change? To understand why, consult your textbook for information on pH buffering.

Do your results support or deny the validity of your stated hypothesis?

Do your results provide a solution to the stated problem? If not, how would you modify what you have done so far to make the problem more amenable to solution?

The process that you have just completed, from the formulation of a question to obtaining and interpreting results that may answer the question, contains all the basic elements of problem solving commonly used in science and, in a less formal manner, in everyday activities.

B. Dissolved Oxygen Content of Water—A Descriptive Approach

The techniques outlined in the next exercise are based on a descriptive approach to answering the following question.

Question:

What is the dissolved oxygen concentration of the water samples provided?

Obviously, there is no reasonable hypothesis to propose, so there can be no hypothesis testing. Instead, the procedures outlined in the next exercise are intended to provide a descriptive answer to the question. As you work through this procedure, refer back to figure 1.1 to make sure you understand the differences between experimental and descriptive approaches to problem-solving in science.

Exercise 2

Some Physical and Chemical Properties of Seawater

Introduction

Compared to most terrestrial environments, the ocean is a relatively stable medium in which to live. Conditions such as temperature, salinity, and amounts of dissolved oxygen and carbon dioxide characteristically fluctuate only slightly over daily or even seasonal cycles. Nevertheless, the variations that do exist, however subtle, are extremely important in determining the type and distribution of organisms that are found.

To develop an appreciation for some of the problems continually encountered by marine organisms, you must first be able to measure some of the more critical physical and chemical properties of the medium in which they live. This exercise is designed to acquaint you with some techniques for measuring density, salinity, and dissolved oxygen. Each of these techniques will be employed in several subsequent field and laboratory experiments. These techniques are not important by themselves but should be considered simply as additional tools to extend your understanding of the marine environment.

I. Density

Density is a property of all types of matter, including water. Precisely defined, density is the ratio of the mass of a substance to its volume. For instance, we may take 100 lbs. of styrofoam and 100 lbs. of lead and recognize that their weights are the same. Yet, when we compare a unit of volume of each, say a cup, we recognize that a cup of lead weighs more than a cup of styrofoam. Hence, lead has a greater density than styrofoam.

The density of seawater varies from place to place in the ocean, depending on evaporation and rainfall rates, river runoff, and water temperature. The density of the water in which they live influences several aspects of the lives of marine organisms, such as the flotation of planktonic and nektonic forms. In addition, sinking masses of higher density seawater carry oxygen-rich waters from the surface to greater depths, as less dense nutrient-rich water moves upward.

When measuring the density of a substance, a standard must be used for comparison purposes. Since the density of water varies with its temperature, the architects of the metric system set the standard using pure water at its most dense temperature, 4° C. By definition, they agreed that one milliliter of pure water at 4° C weighs one gram and occupies one cubic centimeter of space. How does the density of seawater at temperatures other than 4° C behave? The following portion of this exercise examines these relationships. Use a 100 ml volumetric flask and balance to accurately measure and weigh 100 ml of distilled (pure) water. Record the weight in table 2.1. Repeat the same procedure for 100 ml of seawater. From these measured values, calculate their densities and record in table 2.1.