Coastal Ecosystem Management

A TECHNICAL MANUAL
FOR THE CONSERVATION
OF COASTAL ZONE RESOURCES

JOHN R. CLARK
The Conservation Foundation

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A WILEY-INTERSCIENCE PUBLICATION

JOHN WILEY & SONS, New York • London • Sydney • Toronto

Published by John Wiley & Sons, Inc.

Library of Congress Cataloging in Publication Data:

Clark, John R. 1927–
Coastal ecosystem management.

"A Wiley-Interscience publication."
Includes bibliographical references and index.
1. Seashore ecology. 2. Coastal zone management. I. Title.

QH541.5.S35C54 639'.9'09146 76-40125
ISBN 0-471-15854-2

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Preface

Environmental management is a form of art that prospers in direct proportion to the scientific knowledge on which it is based. While technical aspects vary somewhat from locale to locale, the practice of the art varies immensely. Mangrove coastlines are one thing, rocky shores another, but the ecological principles are the same. However, a management strategy that will work for an established seaport is only remotely similar to one designed for a developing recreational settlement on a remote piece of shore. The seaport case will test the manager's skills at accommodation, tradeoff, and balance. The remote settlement will test the manager's skill at creative environmental planning. The first draws more on political skills, the second more on technical skills.

This book conveys technical knowledge and methodology and therefore deals more with developing than with urbanized coasts. It focuses on county and municipal regulatory programs. Its advocacy is conservation of coastal resources and realization of the optimum carrying capacity of coastal ecosystems. Its viewpoint is that the simplest and best management strategy is one that is based on understanding nature's systems and optimizing their functions. Its theme is planning, but planners are not the only audience. The book should be useful to officials of all levels of government and to professional ecologists, developers, lawyers, environmentalists, engineers, technical consultants, and students in many fields.

The complexities of natural systems can be dealt with easily enough by grasping a few basic ecologic principles—11 are presented in this book. The complexities of management can be simplified by founding programs on a few basic ecosystem management rules—this book offers 11.

To the extent that environmental management is built on predetermined guidelines and standards for accommodating development, the development review process becomes professional. This book focuses on the techniques for such accommodation and attempts to provide the basis for a professional approach. Because both planning and management have to go beyond generalities and deal with specific types of projects, it provides specific guidelines and implementation standards for 24 different development project types (Chapter 6).

The ideal backdrop for community coastal management is the Federal Coastal Zone Management Program. Under this program, state governments voluntarily participate and receive Federal funds to establish a statewide coastal management plan. The program requires conformance by local governments for participating states and may provide direct benefits including a state and federal approved management framework, technical assistance, and perhaps direct funding. Since this program requires the use of the existing tools and powers of local government for the most part, there will be little new in the way of demand for types of regulatory machinery. However, some restructuring will be needed.

A major viewpoint of this book is that all environmental requirements can be met with little added burden if existing development reviews are streamlined and if the new ones are integrated into a coordinated "one-stop" system. The object is to put the project proposer through a single coordinated review process rather than a long series of separate reviews. Therefore, we have concluded the descriptive part of the book (in Chapter 5) with suggestions for use of existing management tools and for integrating environmental controls into the existing land use and resource management programs of local government.

This is a technical reference book. Its credibility rests on the authority of the hundreds of technical references that are listed and on 41 contributions by specialists in a variety of technical fields (Chapter 7). An extensive technical supplement provides relevant numerical, graphic, tabular, technological, and descriptive data of use in resource inventory, environmental restoration, planning, management engineering, and environmental monitoring and enforcement.

JOHN R. CLARK

Washington, D.C.
January 1977

Acknowledgments

The preparation of this book was supported by grants from the American Conservation Association (New York), the federal Office of Coastal Zone Management (U.S. Department of Commerce), the Griffis Foundation (New York), and the Jesse Smith Noyes Foundation (New York). I am most grateful to the following officers of their respective organizations: George M. Lamb, Robert W. Knecht, Nixon S. Griffis, and Edith M. Muma.

An undertaking of this magnitude requires the vigorous support of scores of colleagues. Most are listed as authors of contributed articles; others include Joe C. Moseley, II, Marc Hershman, and Timothy Alexander. Lionel A. Walford started me on this path and, with support from The Conservation Foundation, directed photographers Michael P. Fahay and James Chess, who supplied many of the illustrations. I also want to thank my Conservation Foundation colleagues, Jack Noble and John Banta, whose help at crucial times was a godsend, and President William K. Reilly, whose patience with delays and mounting costs persisted to the end. To past President Sydney Howe and colleague William J. Duddleson I owe gratitude for originally inviting me to The Conservation Foundation to do this book. I am also most grateful to Roland S. Woolson, Jr., of John Wiley & Sons, editor and helmsman, who steered the book through its more perilous passages.

Among numerous research assistants, the following made outstanding contributions: Catherine Lochner, William MacKenzie, Trevor O'Neill, Paul J. Sarokwash, Ellen Thomas, Michael Walraven, Langdon Warner, Steve Wasserman, Claudia Wilson, and Steven Zwicky. The production of the entire manuscript was most competently supervised by Laura O'Sullivan, who was ably assisted by Elizabeth Schmid, Ann Thompson, and Jacqueline Virando.

Note. This book has been prepared with partial financial assistance from the Office Coastal Zone Management (National Oceanic and Atmospheric Administration, U.S. Department of Commerce). Statements regarding coastal resource management are the opinion of the author and do not necessarily reflect policy of the Office of Coastal Zone Management.

J.R.C.

Contents

Introduction

> It is not enough to think only of conserving what we have. Conservation must be part of a larger effort to create what we want. In a time of massive change, the task must be to maintain a creative balance between the forces of conservation and the forces of development. Only recently and in selected areas where people are applying new high standards to development is this balance becoming possible.
>
> WILLIAM K. REILLY
> *The Use of Land*, Thomas Y. Crowell Co.

The purpose of this manual is to reduce a vast stockpile of ecological data to a few simple principles and rules that can guide our use of coastal lands and waters. It is not within the scope of this manual to present extensive background data or to examine the merits of different opinions or scientific results. In many respects this is a preliminary effort in a new and undeveloped technical field.

We take the view that management of the coastal zone—coastal waters and shorelands—has as a fundamental goal the conservation of coastal ecosystems at the highest achievable carrying capacity, that is, ability to yield resources of value to man.

Our general theme is that coastal ecosystems can be maintained at high levels of health even while urbanization of the coastal zone increases, if there is effective planning. This will require foregoing many traditional economic ventures and community development programs. We believe that the tradeoffs can be accomplished without serious penalty through innovative management programs.

Planning and advance goal setting are as essential for proper coastal zone management as for other critically important national programs. But coastal communities should not wait for the federal Big Brother to force the action. As stated by Alvin Toffler, in testimony before a U.S. Senate Subcommittee (December 15, 1975):

> Failure to anticipate will lead to tragedy in America. By the same token, long-range thinking that is unconnected to the ideas, energy and imagination of our whole population, long-range thinking that is merely top-down, and not equally bottom-up, could also produce the end of democracy.

In this spirit we attempt to provide a comprehensive ecological background for local government decision-making and for building a management framework that will lead to the best achievable ecosystem function and the highest carrying capacity. How far short of this goal any management program falls must of necessity be decided by society, not by science. Although scientists can often state the conditions that are optimum for best ecosystem function, they are not specially equipped to offer advice on what constitutes socially acceptable or unacceptable levels of carrying capacity. In effect, ecological scientists can establish the criteria upon which to judge ecosystem condition and upon which public decision-making can proceed, but are not themselves qualified to make the decisions by virtue of their knowledge.

Whatever its specific goals may be, an environmental management program must embrace whole ecosystems. Any attempt to manage separately one of the many interdependent components of a complex ecosystem will probably fail. So will any attempt to control any one source of environmental disturbance to the system without controlling others. The ecosystem defined must embrace a complete and integral unit, one that includes a coastal water basin (or basins) and the adjacent shorelands to the extent that they have significant influence on coastal waters.

A program for conservation of coastal ecosystems should consist of four major elements: (1) protection of all ecologically vital areas; (2) elimination of all damaging discharges of pollution; (3) control of site alteration in the shorelands to maintain the optimum (natural) quality, abundance, and rate of flow of runoff from coastal watersheds into coastal water basins; and (4) control of excavation and alteration of the coastal water basins and their margins.

In the preparation of a management plan for any coastal area, it will be necessary to make a professional analysis of each coastal ecosystem to determine its values and vulnerabilities and to devise effective controls on potentially adverse activities. The framework for management analysis of an ecosystem must include not only a survey of natural systems and the important biota, but also knowledge of the major physical factors that affect the carrying capacity of the ecosystem and the ways in which these factors interact and in combination govern the life of the system.

Planning requires a system of identification and classification of general areas of critical environmental concern. These are areas within which human activities must be controlled (not necessarily prohibited) to protect the environment. Specific areas that are especially critical ecologically—vital areas—are to be designated for exemption from most uses within areas of concern. The whole of the typical estuarine basin—the estuary and its surrounding tidelands and wetlands—is an area of environmental concern. Coastal floodplains and coastal watershed drainage systems are also designated as areas of critical environmental concern because of their relation to coastal waters.

It is necessary to include the shoreland watershed adjacent to the coastal water basin for a very practical purpose: the flow of water from the land is a primary controlling factor on the condition of coastal ecosystems. Therefore maintenance of the quality and quantity of runoff through regulation of land-use practice is critical. This is a job for local governments, one that requires no new inventions or the fashioning of new tools. The regulatory machinery that is presently operating in the typical coastal community is sufficient to accomplish the local part of the job. Of course, a close integration with regional, state, and federal law, policies, and programs is necessary.

Ecologically, any development activity anywhere in coastal areas—watersheds, floodplains, wetlands, tidelands, or water basins—is a potential source of damage to the coastal waters ecosystem. The amount of damage that may result from any disturbance depends on the characteristics and vulnerabilities of the specific ecosystem involved. Development planning must recognize particularly that modification of the land area has a high potential for adverse effects on estuarine systems by altering runoff patterns and thereby reducing the capability of the land to store rainwater, to regularize its release from the watershed, and to cleanse it enroute to coastal waters.

Water system protection must first address the control of land modification activities, principally those associated with site preparation for development. It should become a standard management goal to maintain intact the natural pattern of freshwater inflow. Certainly, specific constraints should be imposed on project location, design, and drainage engineering throughout the coastal watershed, particularly in its water areas. These constraints should encourage, and in some cases require, the adjustment of traditional practices of residential development relative to density, project design, site preparation, drainage, and other factors. For example, the amount of impervious surface should be minimized and barren soils rapidly stabilized. Finished grades should be designed to direct water flows along natural drainage courses and through natural terrain where the vegetation can cleanse runoff waters. Watercourses (marshes, swamps, bogs, creeks) will have to be exempt from alteration. Moreover, major restoration should be undertaken for highly altered and damaged hydrological systems.

In planning for coastal land- and water-use management, it is necessary to identify, through impact assessment, the specific ecosystem hazards associated with specific types of utilization. Some types of use involve the construction of projects that will lead to gross disturbance of the ecosystem. Other uses may endanger ecologically vital areas or preempt space from them. Still others may cause day-after-day occupancy or operating disturbances lasting for the duration of their existence.

Ecosystems of the confined estuarine water basins are usually ecologically complex and exceptionally rich: "Characteristically, estuaries tend to be more productive than either the sea on one side or the freshwater drainage on the other" (E. P. Odum, *Fundamentals of Ecology,* W. B. Saunders Co.). On the other hand, estuaries are the most sensitive and stress-vulnerable coastal ecosystems of the confined water bodies—particularly those with poor circulation properties. Therefore development adjacent to estuarine waters will require exceptionally vigorous management. For this reason we have given a greater degree of attention to estuaries than to ocean water areas. However, we have also focused attention on the especially rich and vulnerable life systems of the ocean that require protection, such as coral reefs and kelp beds. Although we have not specifically addressed the Great Lakes, many of the principles applying to marine estuaries will be found to be relevant also to the ecosystems of the Great Lakes.

As a practical matter, we have had to recognize that the regulatory agenda must be considered in two management contexts: the ecological context, which reflects the permanent laws of nature, and the institutional context, which reflects the changeable laws and policies of man.

In addition to ecological concerns a major interest of coastal citizens is to acquire better control of growth through new approaches to public policy and law. Uncontrolled development has already undermined much of the value of coastal and estuarine resources and threatens vast damage to the remainder. The demand for permanent retirement and temporary recreational housing and for waterfront land investment opportunities has been intense. Developers have encouraged and then satisfied this demand and in so doing have created high capital and servicing costs. Tax rates have accelerated so that only the most expensive homes are actually paying their own way. The crux of the issue is whether, on the one hand, the governmental controls demanded over the use of private land can be tolerated politically and constitutionally, or whether, on the other hand, the lack of them can be tolerated economically and environmentally.

Even with regulations to provide ecological protection of critical areas, there may be need for a supplementary program of public acquisition to achieve other objectives. Since the supply of funds is always limited, acquisition priorities should be established. Acquisition is particularly needed to ensure public access to scenic, recreational, and other water-related resources. The highest priorities should go to acquisitions that provide access, enhance public recreation opportunity, provide views, or protect specific wildlife habitats. Acquisition priorities should be adjusted in any situation where environmental protection regulations cannot fully apply. In cases of prior irreversible commitment, for example, or adverse court decision, a "defensive" acquisition strategy might be employed which would prevent major ecological disruption and at the same time provide access to quality public recreation and scenic experience.

Starting with a foundation of fundamental ecological principles, we have developed for this manual a number of general management rules and suggested a variety of constraints on coastal development activities. These constraints are aimed at specific uses of coastal waters and shorelands, such as agriculture, marinas, or residential development. Chapter 7, a collection of articles by various specialists provides a detailed factual background, and an Appendix of tabular and graphical matter supplies useful technical data.

CHAPTER ONE

Ecology

Ecology is the science that treats the interrelations of living forms and their environments. The environment of any one species includes all the physical forces that influence it and all other species that affect it. The word "ecology," as we use it here, has the broad connotation of treating whole communities of life. Our discussion focuses on the *coastal waters ecosystem*—the basic functional geographic unit that embraces all of the life and physical components involved with a distinct coastal water basin. It also includes the stretch of shorelands that have immediate direct influence on the coastal water basin.

The ecosystem orientation toward management of the coastal zone stresses that, to be effective, the administrative area must be a coupled unit of coastal water basin and adjacent shorelands. The governing Ecological Principle is: *The carrying capacity of a coastal water basin is controlled by all factors that influence the function of the ecosystem of which the basin is a part* (No. 1).

The essential qualities of a coastal ecosystem are features, processes (limiters), modulators, and characteristics. Features are the fixed physical objects, such as coral reefs, mud flats, or grass beds. Processes are the energy flows that "drive" the system, such as sunlight, water flow, or nutrient recycling; their rates of flow limit the productivity of the system. Modulators are the variable factors that limit carrying capacity on a short-term (often day-to-day) basis, for example, temperature, available mineral nutrients, dissolved gas concentration, or presence of toxic chemicals. Characteristics are the qualities that give each coastal water basin its distinctiveness, such as the species mix (the relative numbers of various species present), the general water condition, or the visual appearance of the basin (water and marginal area). An understanding of these factors is useful in devising ecosystem management programs. A system of evaluation and classification is required that can simplify the nearly limitless complexities of nature (see Chapter 3).

In this chapter we briefly describe some of the major features, processes, and modulators that control the carrying capacities of coastal water basins. This is not meant to be a comprehensive treatise on ecology; rather it is the briefest account possible of the essential properties of coastal ecosystems and the basic governing principles.

The shorelands regime (coastal watershed) is considered in regard to the aspects that have major influence on the function and carrying capacity of the coastal waters ecosystem (brackish to salty waters). The major focus is on the estuarine regime—the protected system of bays, lagoons, and other inner waters of the coastal zone—which is both the richest and the most vulnerable sector of the coastal waters. The seashore and ocean waters regime is given much less attention because it is both safer from disturbance by human society and of lesser interest to coastal management at the local level. Barrier islands are singled out for special attention because they have extraordinarily high resource values, because they are very vulnerable to ecological damage, and because the need for controls is so urgent.

THE GEOPHYSICAL SETTING

Coastal water ecosystems operate within the confines of existing geological structures, for example, deep rocky fiords, "drowned" river valleys, or shallow, marshy embayments between sand ridges (Figure 1.1). Similarly, systems in the shorelands operate within the geological confines of the watershed. The geological features themselves are modified over time by dynamic weathering forces—wind, water flow, erosion, waves, sedimentation—and by the effects of vegetation.

A wide ocean (continental) shelf is generally associated with extensive low-lying shorelands and a wide band of salt-marsh wetlands next to the coast, while a narrow shelf is associated with steep or mountainous shorelands. These associations and their characteristic ecosystems differ greatly from one coastal region to another.

Northern shores once covered by ice—New England, Puget Sound, and southeast Alaska—are sharply sculptured with generally steep shorelines marked by deep, heavily indented embayments, islands, steep rocky shores, and irregular bottom topography.[2]

The parts of the Atlantic and Gulf coasts that were unaffected by glaciation consist of relatively flat terrain in which wide coastal embayments and salt marshes are the predominant features. These are coasts that were formed primarily of sediments eroded from ancient mountains, and along which embayments and salt marshes form traps for sediments the rivers bring down to the shore. In time, deltas may be formed, stretching out into the sea. These coasts are characterized by great expanses of shallow water and aquatic vegetation. They have extensive sand dunes, and sandy ocean beachfronts are backed by well-developed estuaries (the protected waters of embayments, lagoons, and tidal rivers).

The constant input of sediments from erosion tends to fill up the estuarine basin. The most rapid sedimentation occurs in the inner, low-salinity portion of the estuary. Here salt water meets fresh, coalescing riverborne silts into larger, heavier particles that settle out as the estuary broadens and the flow slackens (Figure 1.2).

The form, or shape, of the estuarine water basin controls the ecological system largely through the secondary effects it exerts, that is, by influencing such factors as currents, temperature, vegetation, and flushing rate (the rate of replacement of the water in a basin). For example, the structure of a typical estuary sets up a pattern of currents that retains nutrients, sometimes called a

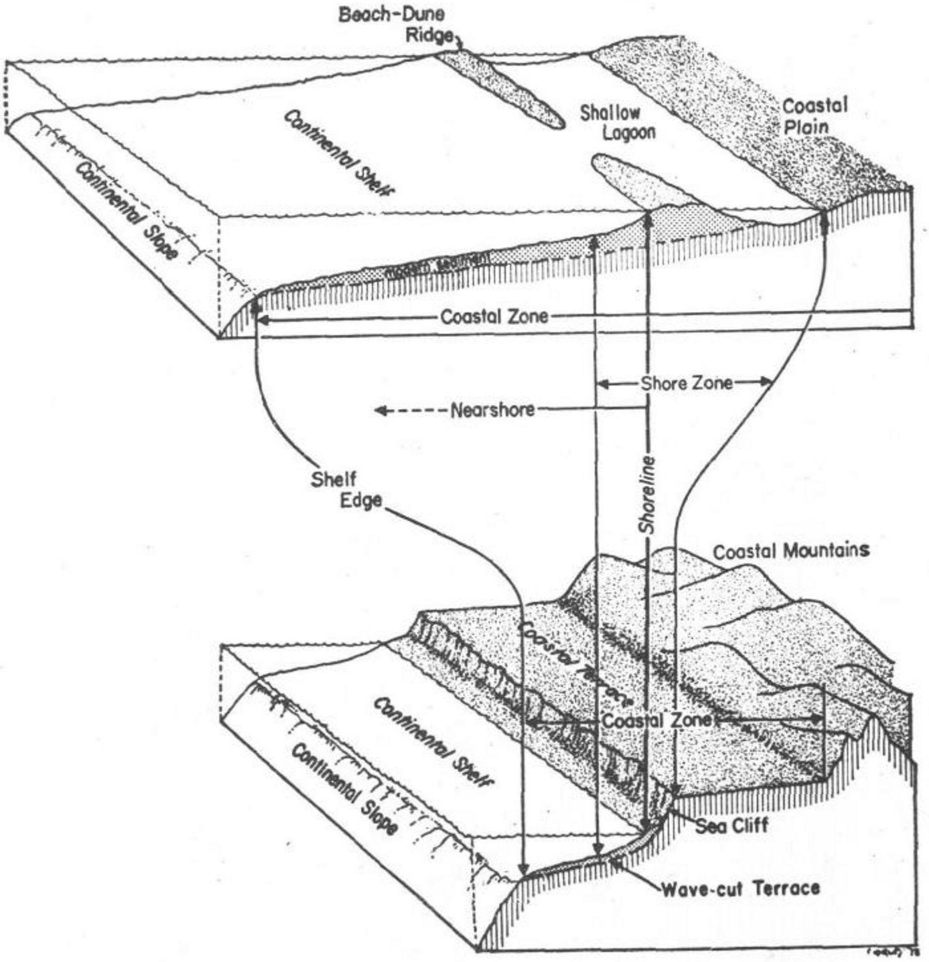

Figure 1.1 Wide-shelf plains coast (upper) characteristic of the U.S. east coast (trailing edge), and narrow-shelf mountainous coast (lower), characteristic of the U.S. west coast (collision edge). (SOURCE: Reference 1.)

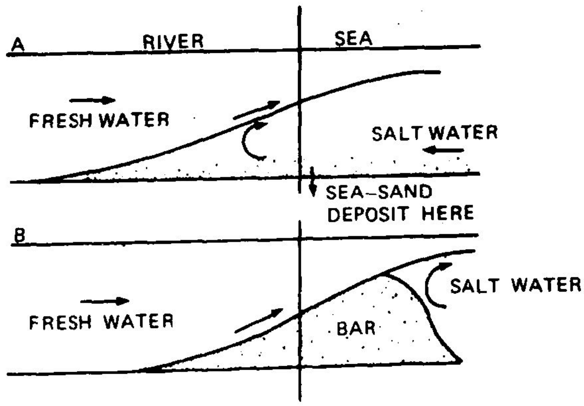

Figure 1.2 Formation of an estuarine sand bar. (SOURCE: Reference 3.)

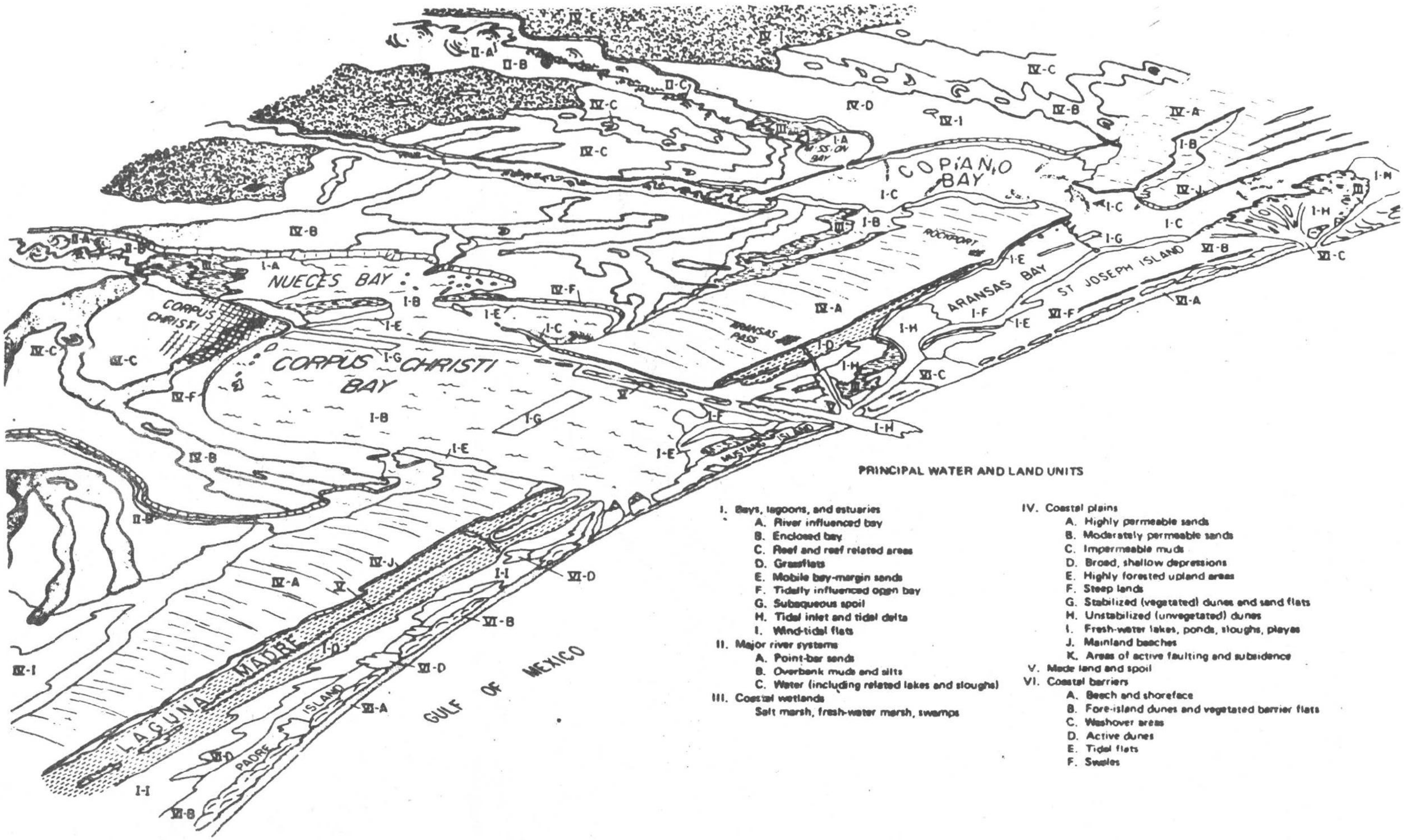

Figure 1.3 Ecological subsystems (or environmental capability units) around Corpus Christi Bay, Texas, which include 34 distinct categories. Each will respond differently to similar environmental stresses. (SOURCE: Reference 4.)

"nutrient trap"; this condition is favorable to the development of a rich and varied community of coastal water life.

The effect on a coastal water ecosystem of any particular environmental disturbance depends partly on the geological form of the ecosystem basin and the ecological characteristics induced by that form. Furthermore, different subecosystems may be expected to react differently to a particular type of disturbance, depending on their forms (Figure 1.3).

The coastal waters of the United States may be conveniently divided into large biogeographical regions. These regions vary in such factors as climatic condition, the oceanographical characteristics of the seas that border them, and the way in which they are influenced by the type of land mass that lies behind them. Among climatic variables, temperature is often the primary determinant of the distribution of species of plants and animals throughout the coastal zone. Other significant climatic factors are the amount and the pattern of precipitation, of wind, and of sunlight. Large-scale oceanic forces that influence coastal ecosystems are prevailing wind and waves, permanent coastal currents, persistent coastal upwellings, massive oceanic currents, and other factors that vary from place to place along the coast. Most climatic and oceanic forces are beyond human control, but society can significantly control the ways in which the land surface influences coastal ecosystems.

ECOLOGICAL CONCEPTS

The biota of a coastal ecosystem includes a great variety of plants, birds, fish, mammals, and invertebrate organisms (Figure 1.4). In its natural condition the ecosystem is a balanced network of biotic relationships that is all too easily upset by pollution and other man-made disturbances. Fortunately, existing ecologic theory and knowledge are sufficiently advanced to provide a basis for sound protection programs.

Within the subject matter of ecology there are a number of concepts that relate directly to protective management of coastal ecosystems. These concepts provide a framework for understanding how organisms interact with the forces and conditions of their environments and survive or suffer damage. The following discussion serves to explain briefly the more relevant of these concepts.

Carrying Capacity and Standing Crop

Carrying capacity is the limit to the amount of life that can be supported by a specified habitat; most narrowly, it is the number of individuals of a particular species. It is always used as a *potential*. The *actual* number (or mass) of species present in an area at any one time is the *standing crop*. In a wider sense carrying capacity expresses the total amount (numbers or mass) of beneficial life that an ecosystem or subsystem can support.

Thus, in the ecological sense, carrying capacity is the ultimate constraint imposed on the biota by existing environmental limits, such as the availability of food, space, or breeding sites, or by disease or predator cycles, temperature, sunlight, or salinity. The carrying capacity of a system can be markedly reduced by man-made disturbances that reduce available energy supplies or interfere with energy utilization.

The term "carrying capacity" is often used by planners in a more general, nonecological sense, for example, as an expression of the reasonable capacity of an area's resources to support human occupancy or activities. In addition the term has found use in social and economic sciences. Therefore it is always important to understand the specific context in which "carrying capacity" is used.

In the sense in which it is generally used in this book, *"carrying capacity" expresses*