Fisheries Management

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FISHERIES MANAGEMENT

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Contents

PRINCIPLES OF MANAGEMENT

MANAGEMENT OF FISHERIES

Preface

The objective of this book is to present a broad discussion of fisheries management for use by students as a textbook and by professionals as a reference. In this sense, we felt that the knowledge and experience represented by the 16 authors, all experts in their topics, far surpassed the possible inconvenience of an edited text. The diligence and cooperation of the authors have shown this to be the case from the viewpoint of the editors, and we are confident that readers will agree.

Since the time of preparation of the text, two authors have changed their professional affiliations. Robert T. Lackey is with the National Water Resources Analysis Group, U.S. Fish and Wildlife Service, Kearneysville, West Virginia, and Michael K. Orbach has moved to the Center for Coastal and Marine Studies, University of California at Santa Cruz. Dora R. May Passino, of the Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service, Ann Arbor, Michigan, and Adam A. Sokoloski both prepared their chapters on personal time and at private expense.

Several authors wish to express special thanks to those individuals which contributed directly to the preparation of their chapters. Charles E. Warren and William J. Liss acknowledge the careful review of Chapters 2 and 3 by Terry Finger, Hiram Li, Becky McClurken, Dale McCullough, and Marion Ormsby. John Cairns, Jr. acknowledges the help of Darla Donald in the editing and preparation of Chapter 10 and Betty Higginbotham and Angela Miller for the final typed copy. Peter A. Larkin recognizes the contributions of Carl Walters and Helen Hahn to the preparation of Chapter 11. Vincent F. Gallucci wishes to thank M. Griben, T. Quinn, II, and C. Rawson, who enthusiastically criticized his contribution to Chapter 5, and P. Smith, who make several useful comments. Ms. C. Anderson cheerfully endured the retypings that result when the authors are from different universities. Chapter 5 was partially supported by the Washington Sea Grant Program and the Oregon State University Sea Grant Program. Chapter 14, by J. L. McHugh, is Contribution 268 from the Marine Sciences Research Center, State University of New York, Stony Brook.

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L.A.N.
Blacksburg, Virginia R.T.L.

CHARACTERISTICS OF FISHERIES

Chapter 1
Introduction

LARRY A. NIELSEN AND ROBERT T. LACKEY

1.1 PERSPECTIVE

If the average citizen were asked to picture a fisheries scientist, he probably would imagine a biologist who spent his time collecting fish, identifying them, and describing their life histories. This caricature, however, is a fairly accurate impression of an ichthyologist, not a fisheries scientist; the study of fish is only part of the broader study of fisheries. In most universities, the study of fisheries is conducted within a College of Agriculture or Natural Resources rather than in a biology or life sciences department. Programs in agricultural sciences characteristically address such topics as economics, farm and ranch management, processing of animal and plant products, and techniques for efficient harvest as well as biologically-oriented topics such as genetics, nutrition, and disease. Similarly, a fisheries manager not only deals with fish and their biological characteristics, but also must consider such things as who will use the resource, how much it will cost to manage effectively, and how environmental changes will affect the resource.

A fishery may be defined in this broad sense as a system composed of three interacting components: the aquatic biota, the aquatic habitat, and the human users of these renewable natural resources. Under this definition, we find a diversity of systems ranging from whale fisheries in the open ocean to brook trout fisheries in isolated alpine lakes, from subsistence fisheries for seal in northern Canada to fisheries for aquarium species in the tropics. Each component of a fishery influences how that fishery performs, and understanding the entire system and all its parts is essential to the successful management of a fishery.

1.2 AQUATIC BIOTA

Most fisheries are classified in terms of the product harvested, that is, the target species, for human use (Rounsefell 1975). Thus we speak of fishing for salmon, trawling for cod, or spearing bullfrogs. The types of organisms which are used directly or indirectly by humans cross virtually all taxonomic categories.

Whereas the human consumption of aquatic organisms in North America is limited to a relatively small number of fishes and shellfishes such as flatfish, salmon, tuna, shrimp, and oysters, diets in many cultures include a large variety of aquatic organisms. In Japan, where annual consumption of fisheries products approaches 40 kg per person, the weekly menu for a typical family may include several types of finfish, shrimp, squid, sea urchin, and kelp.

Beyond their uses as harvestable products, however, aquatic organisms affect in many ways the nature of a fishery. The type and number of organisms which make up the aquatic food web partially will determine how many target organisms are produced and can be harvested. Natural competitors, predators, and parasites may reduce the abundance of target organisms or alter the size and quality of the desired products. The increasing emphasis on maintaining rare species provides another dimension in which aquatic organisms affect decisions regarding fisheries management. Approximately 100 aquatic species are considered endangered or threatened, and that number promises to grow in the future.

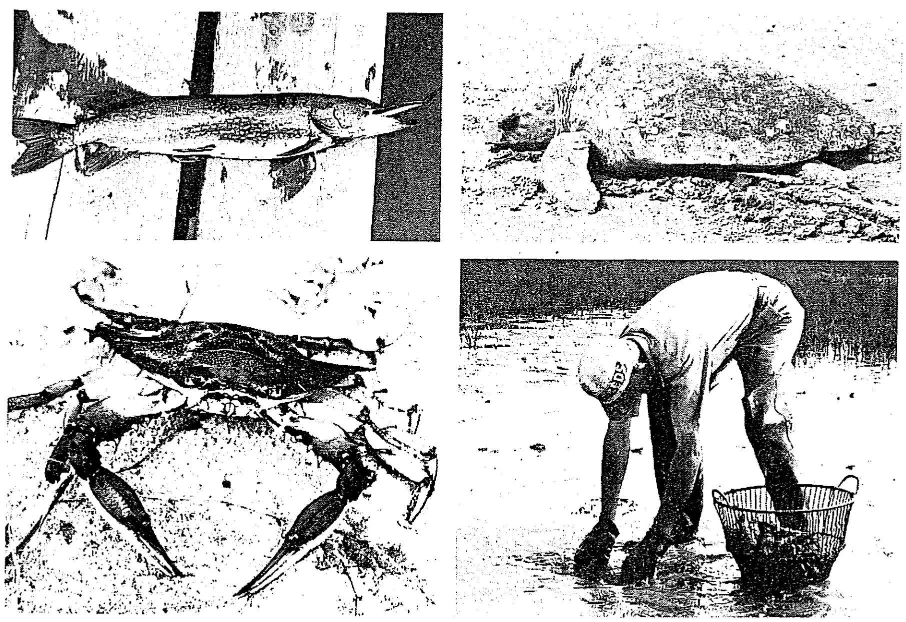


Fig. 1.1. Aquatic resources are typically categorized by target species: *top left* Northern pike, a popular recreational fish; *top right* loggerhead turtle, a species threatened by extinction; *bottom left* blue crab, a valuable crustacean in coastal fisheries; *bottom right* oyster, a mollusc harvested by commercial and recreational fishermen. Top left photograph by courtesy of U.S. Forest Service, remainder by courtesy of Fish and Wildlife Service.

The so-called finfishes are vertebrates in classes Agnatha, Chondrichthyes, and Osteichthyes and are the most common target species of traditional fisheries. Finfishes range from species such as menhaden, which are of low value and are used for industrial products, to highly valued species such as tuna and salmon. Recreational uses of the aquatic biota are centered around the finfishes, which accounts for the restricted perspective from which many Americans view fisheries. Angling in freshwater is aimed primarily at a few species of predatory fish, principally sunfishes, bass, perch, trout, and catfish. The diversity of finfishes in marine habitats is much higher, and the variety of the angling catch also is greater.

Certain species of mammals are the targets of highly-publicized fisheries. Catches of whales, dolphins, seals, and sea otters were much greater before 1900 than at present, both because of great declines in abundance and because substitutes for the products of such fisheries are now available. Emotional attachments to mammalian species and competition among nations for their capture, however, foster continued interest out of proportion with the current commercial value of these fisheries.

Crustacea constitutes perhaps the most important group of fisheries organisms. The larger forms, including shrimps, lobsters, crayfish, and crabs, are heavily exploited for human consumption. While the total catch by weight is much lower than that of finfishes, the commercial value of all crustaceans landed in the United States is approximately equal to the value of all landings of finfishes. In addition, the smaller forms of crustaceans are members of most aquatic food chains leading to harvestable products. The 'krill' which are strained by baleen whales are crustaceans, as are the cladocerans and copepods which are eaten by most finfishes.

Mollusca forms a commercially important group which illustrates the breadth of uses from aquatic resources. Clams, oysters, squid, and octopus are examples of molluscs which are highly valued for human consumption. The value of commercial landings of molluscs in the United States is about one-third the value of crustaceans. Prior to extensive use of plastics, the shells of molluscs were the raw material for the production of buttons and other decorative ornaments. Bivalue molluscs also are the source of natural pearls, and cultivation of molluscs for pearl production is an important industry. The collection and marketing of shells remains an important recreational activity and tourist industry in coastal resorts.

Representatives of most other phyla, including aquatic plants, have some commercial and recreational importance, directly or indirectly. Many fisheries are of little importance on a world-wide scale, but may be important in localized areas where density of an organism is high enough to permit harvest and where a local market exists. Many types of aquatic organisms which presently are not utilized are likely to become targets of fisheries as demands for food and other products become greater with increasing world population. The great diversity of the aquatic biota is a valuable resource of itself, and exploitation of that diversity will increase as knowledge of the distribution, abundance, and usefulness of various organisms increases.

1.3 AQUATIC HABITAT

The aquatic habitat includes the non-living aspects of the aquatic ecosystem. The study of aquatic habitats is the subject of disciplines called physical limnology (freshwater) and oceanography (marine), and understanding gained from these fields is essential to the proper management of fisheries resources. While it is tempting to assume that our experience with terrestrial habitats is sufficient to guide management of aquatic habitats, we must realize that the aquatic habitat is foreign to land animals and adaptations to aquatic habitats usually are quite different than adaptations observed on land.

Aquatic habitats may be classified by a variety of criteria including salinity, size, depth, origin, and rates of water flow. On the basis of salinity, waters are described as freshwater if the concentration of dissolved ions is lower than 0.5 parts per thousand, saltwater if the concentration is higher than 35 parts per thousand, and estuarine or brackish in between those concentrations. Whereas the salinity of most marine systems is very similar, fresh and brackish waters vary greatly in concentration of ions, depending on location, watershed use, and season.

Freshwater systems can be divided into standing waters, including lakes, ponds, and reservoirs, and flowing waters, including streams and rivers. Natural lakes are formed in many ways, but most in the northern hemisphere were formed by glacial activity within the last 20,000 years. Glacial lakes contain primarily coldwater or coolwater fish species and, because the lakes are young in an evolutionary sense, the same species occur across broad geographic regions. Some large lakes, such as Lake Baikal in Siberia and Lake Victoria in Africa, are over one million years old and contain many species which are found only in these lakes.

Standing waters are created by man when watersheds are dammed; the impounded waters can be defined as ponds if smaller than two hectares and reservoirs if larger than two hectares. More than four million ponds exist in the United States, mostly in agricultural areas where they have been constructed to aid in soil and water conservation. Although ponds are common parts of the rural landscape, their management for fisheries resources is frequently restricted by small size, private ownership, poor water quality, and other conflicting uses. In Asia, aquaculture is practiced in small ponds which are stocked with various species of carp and are fertilized with wastes from other domestic animals.

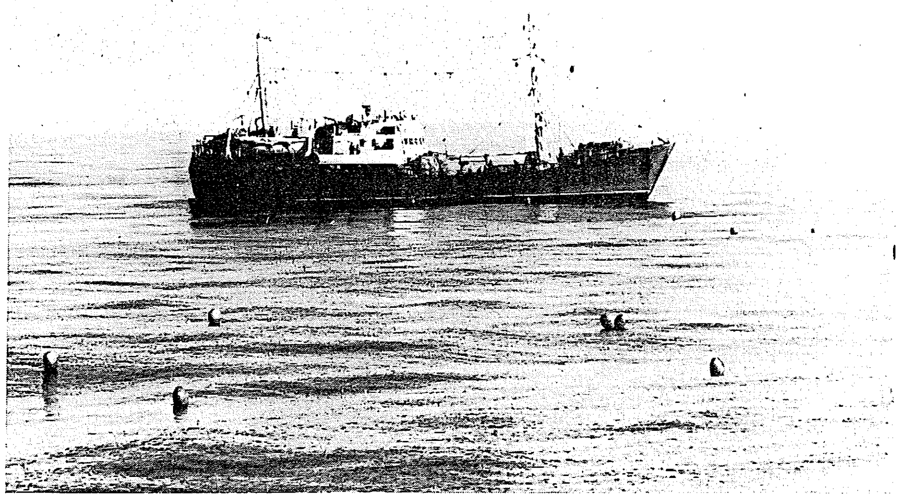
Reservoirs occur when relatively large streams or rivers are dammed for controlling floods, producing power, irrigating farmland, or establishing domestic water supplies. Reservoirs generally are constructed to serve several purposes, and the production of fish is usually of secondary importance. Nevertheless, almost one-third of the total recreational fishing in North America occurs in reservoirs, mostly on those larger than 200 hectares. Large reservoirs in Europe generally are managed for the production of commercial crops. The habitat in reservoirs is intermediate between a lake and a stream, which provides both great opportunity and difficulty for management.

Flowing waters are divided loosely into streams or rivers on the basis of size and location. Rivers are larger flowing waters which typically discharge into the marine environment. Throughout history, rivers have been an important resource for man, providing transportation, sewage disposal, and water supply for riverside communities. A quick glance at a map will reveal that most major cities lie along rivers and that most rivers are densely settled with cities of all sizes. Fisheries in rivers frequently suffer because industrial and other uses render the water unsuitable for fish life. Aside from residential species, most rivers contain migratory fish populations which use the freshwater habitat for spawning and for rearing of young fish and spend their adult life in the ocean.

Streams generally are small and drain the upper sections of watersheds. Because streams carry little water and may contain water for only part of the year, they are not used for the same variety of purposes as rivers. Streams provide variety to the landscape and contain ideal habitats for trout and other species important for recreational fishing. More than any other aquatic system, a stream is intimately associated with the surrounding watershed; water level and quality is extremely variable, depending on weather and land use patterns.

Estuaries are the boundaries between freshwater and marine systems and are extremely important from a fisheries standpoint. All migratory species, including salmons, eels, and striped bass, pass through estuaries on their journey between fresh and salt water. Because estuaries receive all the nutrients carried by river water and because they are shallow and the water is well-mixed, the production of aquatic organisms is very great. This high productivity supports valuable fisheries for many aquatic invertebrates and is ideal for the rapid growth of young fish which will later migrate to marine habitats. Estuaries also are important for human commerce, and major cities exist on the shores of most estuaries. The impact of dense human population often conflicts with the ability of an estuary to remain a suitable habitat for fisheries.

Marine systems may be divided arbitrarily into coastal habitats, where water is shallower than 200 meters, and open ocean habitats. Coastal habitats occur adjacent to continental land masses and encompass traditional fisheries areas such as the Grand Banks near Newfoundland, the North Sea, and the Barents Sea. Coastal habitats are similar to estuaries because they are relatively shallow,



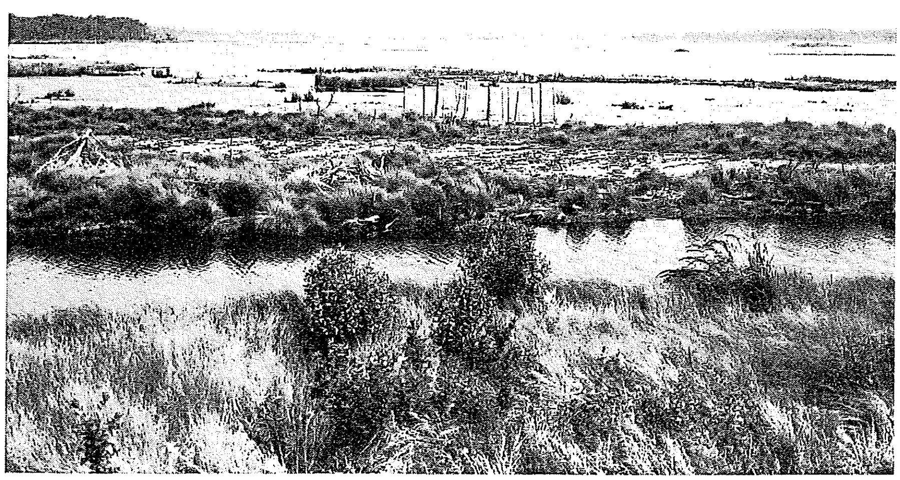
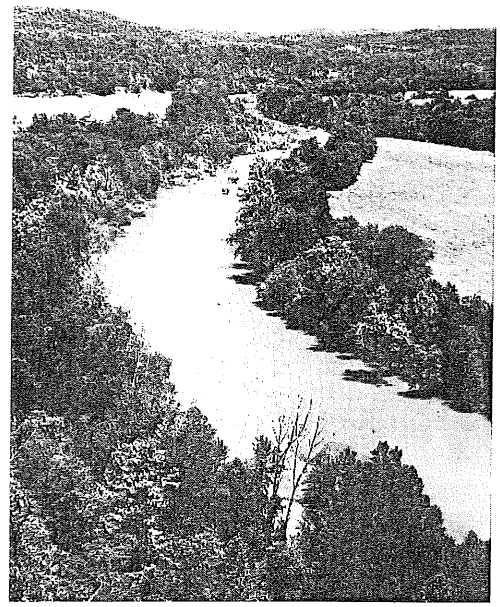


Fig. 1.2. The aquatic habitat is diverse.
FACING PAGE *top* open oceans are important for many purposes, only one of which is fishing; *bottom* estuaries are the 'nurseries' of major fish populations;
THIS PAGE *top* rivers and streams are important for many reasons, not the least of which is as a corridor for migratory fishes; *bottom* lakes, ponds, and reservoirs support many different types of fishing activities.
Photographs courtesy of U.S. NOAA (facing page top), Fish and Wildlife Service (facing page bottom), National Park Service (this page top), and Soil Conservation Service (this page bottom).



have high inputs of nutrients from the adjacent continents, and are very productive. They also are vulnerable to disturbance by the intensity of human activity along the coast.

Despite the fact that oceans cover three-quarters of the earth's surface, the productivity of fisheries resources from the open oceans is rather low. The open ocean sometimes is described as an aquatic desert in which low concentration of essential nutrients is the limiting factor. The great depth of the oceans prohibits the circulation of nutrients to the upper waters where photosynthesis can occur. The difficulty of locating and catching fish in the open ocean also makes most fisheries impractical. Large species such as whales and tuna can be harvested profitably, but only by very modern fleets utilizing advanced technology.

1.4 HUMAN USES

The third component of a fishery consists of the uses and users of the resources. More than any other topic in fisheries management, consideration of the human component is generally ignored. Most fisheries scientists and managers are oriented toward the biological sciences and find study of human aspects difficult or irrelevant. This attitude impedes the management of natural resources since economic, political, or social realities may overrule the wisest plans for biological or habitat management.

Commercial uses of fisheries can generally be categorized as either large industrial or small localized operations. The large industrial fisheries are characteristic of the more developed nations which apply modern technology and large capital expenditures to the capture or culture of fisheries organisms. Such fisheries utilize highly-sophisticated networks including airplanes and radar to locate fish and a diversity of ships which capture fish, store and process the raw products, and transport finished products directly to markets. Within lesser developed countries, fisheries are pursued on a smaller scale. Catches are intended for use by the fisherman and his family group (subsistence fisheries) or for a local market. Techniques used in subsistence fisheries rely heavily on manual labor, and methods may have changed little over thousands of years.

Use of aquatic systems for public recreation tends to occur only in industrialized nations. Likewise, concern for aquatic organisms and environments is restricted to areas with very high standards of living. In Europe and especially in North America, the indirect economic benefits associated with recreational fishing are substantial and lead to competition between recreational and commercial uses of particular fisheries.

1.5 SPECIAL ATTRIBUTES OF FISHERIES

The many-faceted nature of fisheries and fisheries management creates an exciting environment for the professional manager. Opportunities for progress in management of biota, habitat, and users exist if the fisheries professional is willing to augment his own capabilities with the tools and approaches of many disciplines. The opportunities of any diverse management system, however, are accompanied by a set of factors which work against effective management. Fisheries management is no exception.

Fisheries are parts of complex and unpredictable ecosystems. Floods, droughts, temperature cycles, and fluctuations in the abundance of organisms are examples of factors which are uncontrollable and often occur with little or no warning. When scores of such factors operate within a single ecosystem, the result may resemble a kaleidoscope—ever-changing and never predictable. Even for the few fisheries systems which have been well studied, the predictive capability of fisheries managers is disappointingly poor. In such cases, we speak of *random* or *stochastic* processes, which is just another way of stating that our understanding is insufficient to allow prediction.

Aquatic systems also are highly *dynamic*. In this sense, dynamic means that many things are occurring which may not be detectable when the system is observed at a single instant. The number of fish in a pond may be about the same in April of each year, but during the year, some fish have hatched, grown, died, and been caught. Each of those dynamic processes may be affected by the environment, the abundance of fish, and each other. These processes also tend to reduce the influence of changes to a system, whether such changes are undesirable, as in the case of a spill of pollutant, or desirable, as when a fisheries manager tries to improve fishing. Thus, dissecting the system into its component parts is essential to understanding how the system might respond to different conditions.

Added to the difficulties of a complex and dynamic ecosystem is the inescapable fact that aquatic ecosystems are *foreign* to man. Men are terrestrial creatures who can directly observe aquatic systems in superficial ways only. The wealth of literature, art, and mythology which relates to the ocean and its creatures is indicative of the aura of mystery that surrounds the aquatic habitat. Because men cannot experience the habitat as a fish, whale, or clam would, fisheries scientists must rely on indirect observations. We lower nets, bottles, thermometers, and cameras into the water and attempt to explain what is happening and why with the help of statistical analysis. While statistics is a helpful tool for analyzing data, statistics cannot decide whether the data are *accurate*, that is, representative of the true situation. In terrestrial ecosystems, the accuracy of data is evaluated by comparing sampling data to direct human observations. In aquatic systems, however, such comparisons usually are impossible and the accuracy of fisheries data must be regarded with caution.

When we consider the human component of fisheries management, we confront the problem of defining and measuring the benefits which man receives from management. Clearly, the users of fisheries systems (that is, the fishermen) receive benefits, but how should these benefits be measured? Should we measure the numbers or pounds of fish caught, dollars in the pocket, or amount of recreational use, and how should we compare these? Beyond this is the larger question of defining all the potential beneficiaries of the fishery. Fishermen are only a portion of society; benefits and costs accrue to people who may never catch, eat, or see a fish, but may be for or against recreational and commercial fishing on philosophical grounds. In a world where the availability of natural resources is decreasing and the number of people is increasing, conflict among users of fisheries is inevitable. While it may be discomforting to think of comparing the existence of an endangered species with the production of hydroelectric power, control of floods, or creation of recreational fishing, such comparisons must be made.

The distillation of all these attributes reveals one last characteristic of fisheries management: decisions must be made in the presence of *uncertainty*. There never really is enough information to make a totally confident decision. Also, the quality of information will vary from subject to subject; predictions of how many fish will be in a lake may be very precise while the question of how many fishermen will pursue them may have only a vague or approximate answer. It is an unsettling reality for fisheries managers, most of whom have been trained as biological scientists, to make decisions based on imperfect information. In the broad sense, however, public fisheries are perfect miniatures of society as a whole and are impacted by all the factors which affect all public activities.

The obvious corollary to the above characteristics is that success in fisheries management in large part depends on the personal experience, intuition, and luck of the manager. Indeed, the question of whether fisheries management is an art or a science is a favorite subject for debate by fisheries professionals (professors usually argue that management is science, managers usually argue for art!). While no one can debate the fact that experience improves judgment, the problem, in the words of an old axiom, is that 'experience is a great thing, but it always comes just after you need it.' The scientific principles provided by the study of the natural and the social sciences are the tools with which the creative manager can effectively manage a fishery.

The use of multiple criteria for evaluating success in fisheries management programs has created many possibilities for innovative programs. The basic ideas of population dynamics have flourished to provide better understanding of how organisms respond to fishing. Availability of computers and sophisticated hand-calculators invites every manager to consider complex questions and frees him from many tedious tasks formerly associated with the job. Most nations of the world have extended their areas of coastal jurisdiction for fisheries purposes to 200 miles; this change alone has drastically altered the nature of fisheries management. The environmental movement has brought fisheries management under the scrutiny of a bigger public with different priorities.

Whether the enlarged scope for fisheries management will encourage or discourage future fisheries programs cannot be predicted. When placed within a systems context, a subsystem such as fisheries may be an inconsequential or even detrimental component in the overall goal of improving the quality of life for people. The probability of this is small, but the probability is large that fisheries as we now know them will be changed greatly in the future. Having meaningful inputs into that future is the goal of fisheries management.

1.6 ORGANIZATION OF BOOK

This book is divided into three sections: *Characteristics of Fisheries*, *Principles of Fisheries Management*, and *Management of Fisheries*.

The *first* section of this book introduces the components of a fishery. The study of fisheries is a synthetic science, calling upon many disciplines to provide the necessary background for management. Chapters 2–6 describe the principles of aquatic ecology, the life histories of important fisheries organisms, the mechanics of describing fish populations, and the social-political-economic realm in which users of fisheries function.

The *second* section of the book addresses the principles which apply to the management of fisheries. Chapters 7–10 describe the systems approach, and the subsystems concerning economic, environmental, and policy questions. Chapter 11 addresses management objectives, providing a synthesis of the previous ten chapters.

The *third* section of the book casts the principles and features of previous sections in the context of management for major habitats. Variation in the characteristics of particular habitats and the way fisheries in these habitats are used creates unique management situations and strategies for each habitat type. Aquaculture is included in this section because the culture of fish occurs in a highly-controlled habitat which is uniquely different than the natural habitats of fisheries management.

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