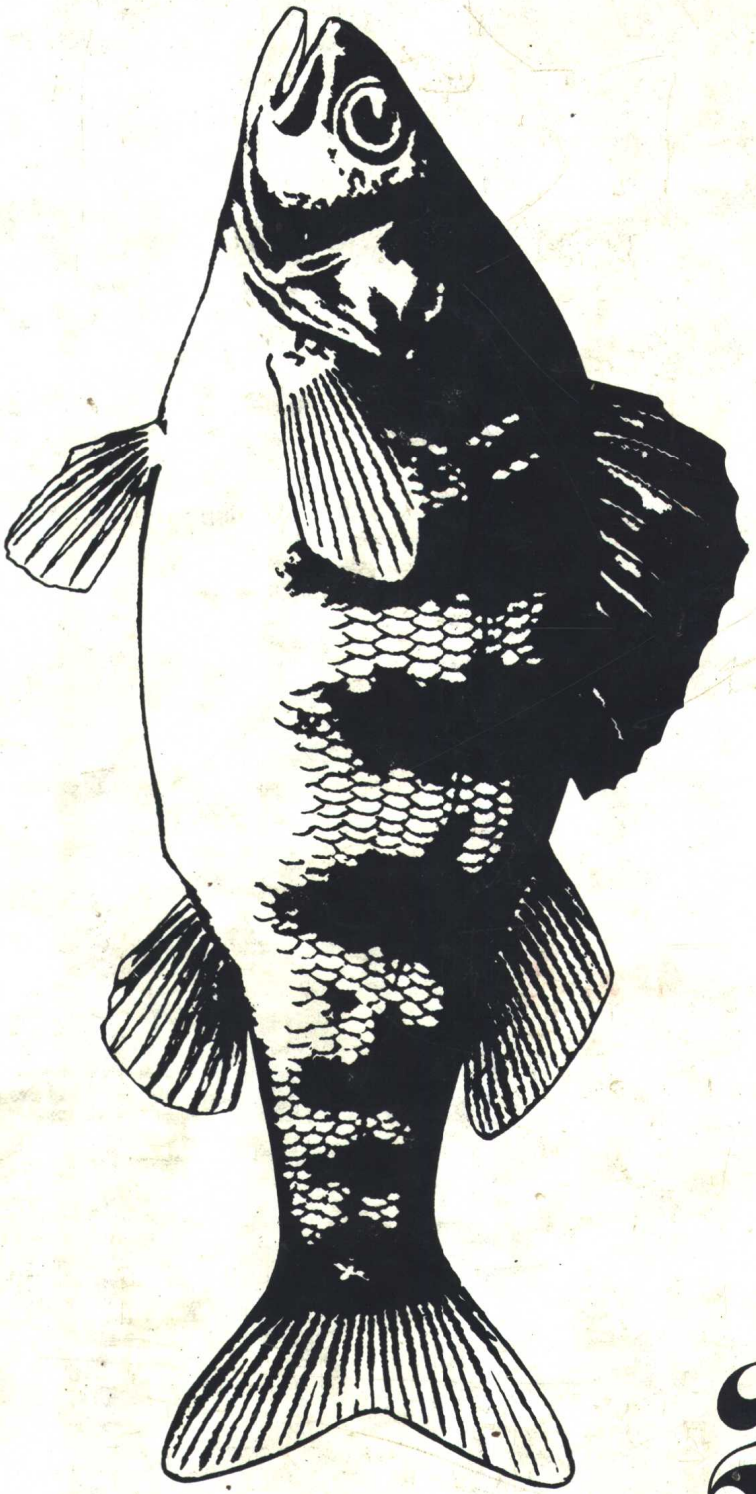

2nd ed

Ichthyology

Lagler Bardach Miller Passino

Ichthyology

Second Edition

KARL F. LAGLER
School of Natural Resources
University of Michigan

JOHN E. BARDACH
Hawaii Institute of Marine Biology
University of Hawaii

ROBERT R. MILLER
Museum of Zoology
University of Michigan

DORA R. MAY PASSINO
Great Lakes Fishery Laboratory
U.S. Fish and Wildlife Service

JOHN WILEY & SONS
New York • Chichester • Brisbane • Toronto

Library of Congress Cataloging in Publication Data
Main entry under title:

Ichthyology.

First ed. by K. F. Lagler, J. E. Bardach, and R. R. Miller.
Includes bibliographies and indexes.
1. Fishes. I. Lagler, Karl Frank, 1912- Ichthyology.
QL615.L3 1977 597 • 76-50114
ISBN 0-471-51166-8

Printed in the United States of America

15 14 13 12 11 10 9 8 7

Dedicated to the late
Carl L. Hubbs
Scholar, Teacher,
and Friend

Preface

In the fourteen some years since the first edition was published, many studies have improved knowledge in ichthyology. A good proportion of these studies have been done elsewhere than in North America and we have drawn on them in this work; but again we have continued to emphasize the use of American examples.

Dr. Dora R. May Passino, fish biochemist, joined us as an author in the current effort, with the kind permission of her employer, the U.S. Fish and Wildlife Service.

We acknowledge with gratitude our indebtedness to our students, colleagues, and other users of the book who have helped us with corrections, criticisms, and ideas. We are especially indebted to Dr. Gerald P. Smith for his help in the revision of Chapter 2 on major fish groups and to Dr. Paul R. Webb for his suggestions for Chapter 6 on locomotion. Most competent technical assistance in the preparation of the revision was given by Elsie Goode, Frances Hubbs Miller, Joanna Schmidt, Mary Lou Lagler, and Donna Brown, and by our Wiley editor, Robert L. Rogers, and production supervisor, Christine Pines.

Karl F. Lagler
John E. Bardach
Robert R. Miller
Dora R. May Passino

Preface to First Edition

Not since David Starr Jordan's venerable *Guide to the Study of Fishes* appeared in 1905 has there been a text reference in ichthyology that drew its examples primarily from the American fauna. We have tried to fill this void with the hope that additional vigorous American students will be stimulated to work in the science of ichthyology and that informed fishermen may further their knowledge of fishes.

Needless to say, there are too many fishes too widely distributed in the vast water areas of the earth for this book to be comprehensive. Although it deals with the broad principles of ichthyology, the treatment of many interesting and important details is very brief or omitted entirely. It is hoped that the progressive student will understand the need for much additional reading. To help in accomplishing this, we have included selected references at the end of each chapter.

The table of contents discloses our efforts to make this book widely adaptable in collegiate courses. We planned it for core reading in both introductory and advanced presentations of ichthyology. However, care may be taken through choice of chapters and sections assigned to make it valuable also for use in courses of comparative anatomy of the vertebrates, vertebrate natural history, comparative physiology, and evolution. Throughout, we have emphasized comparisons among the major groups of fishes both in structure and function.

Early chapters (1 through 3) introduce the diversity of fishes and show the position and content of the major groups, their classification, relationships, and basic structure, with emphasis on living fishes. Chapters 4 through 11 describe and discuss the comparative anatomy and physiology of the classical ten body systems and their integration into the whole fish. Principles of genetics, evolution, systematics, ecology, and ichthyogeography comprise Chapters

12 through 14. Thus a college course in systematic and ecological ichthyology might use primarily Chapters 1 through 3 and 12 through 14, whereas one with emphasis on fish behavior and physiology might use primarily Chapters 4 through 11.

In the preparation of this book we have become greatly indebted to many of our students, colleagues, the publisher, and others. To them we offer our sincere thanks and the wish that they continue to give us the benefit of their indispensable help and criticism. Acknowledgement of illustrations not our own is made beneath each such illustration.

KARL F. LAGLER
JOHN E. BARDACH
ROBERT R. MILLER

Contents

1

Fish, Animals, and Man

WHAT FISH ARE

Fishes are cold-blooded animals, typically with backbones, gills, and fins (rather than pentadactyl limbs), and are primarily dependent on water as a medium in which to live. Their study composes the pure and applied aspects of the science of ichthyology. Obviously not included in this field of learning are mammals, such as whales, seals, and porpoises; reptiles, such as aquatic turtles; and invertebrates, such as clams, shrimp, and lobsters ("shellfish").

Fishes are the most numerous of the vertebrates (Fig. 1.1), with estimates of around 20,000 recent species, although guesses range as high as 40,000. In contrast, it is commonly assumed that bird species number about 8600, mammals, 4500 (of which living man is only one), reptiles, 6000, and amphibians, 2500. Thus, not only are there many different fishes but they come in many different shapes and sizes. Included are pygmies such as the American percid least darter (*Etheostoma microperca*) which matures sexually at a length of 27 mm. and a dwarf pygmy goby *(Eviota)* of the Pacific which breeds at sizes less than 15 mm. There are giants, too, such as the whale shark *Rhincodon),* which has been judged to attain lengths near 21 m. and weights of 25 tons or more. Most fishes are torpedo-shaped, but some are round, others are flat, and still others are angular.

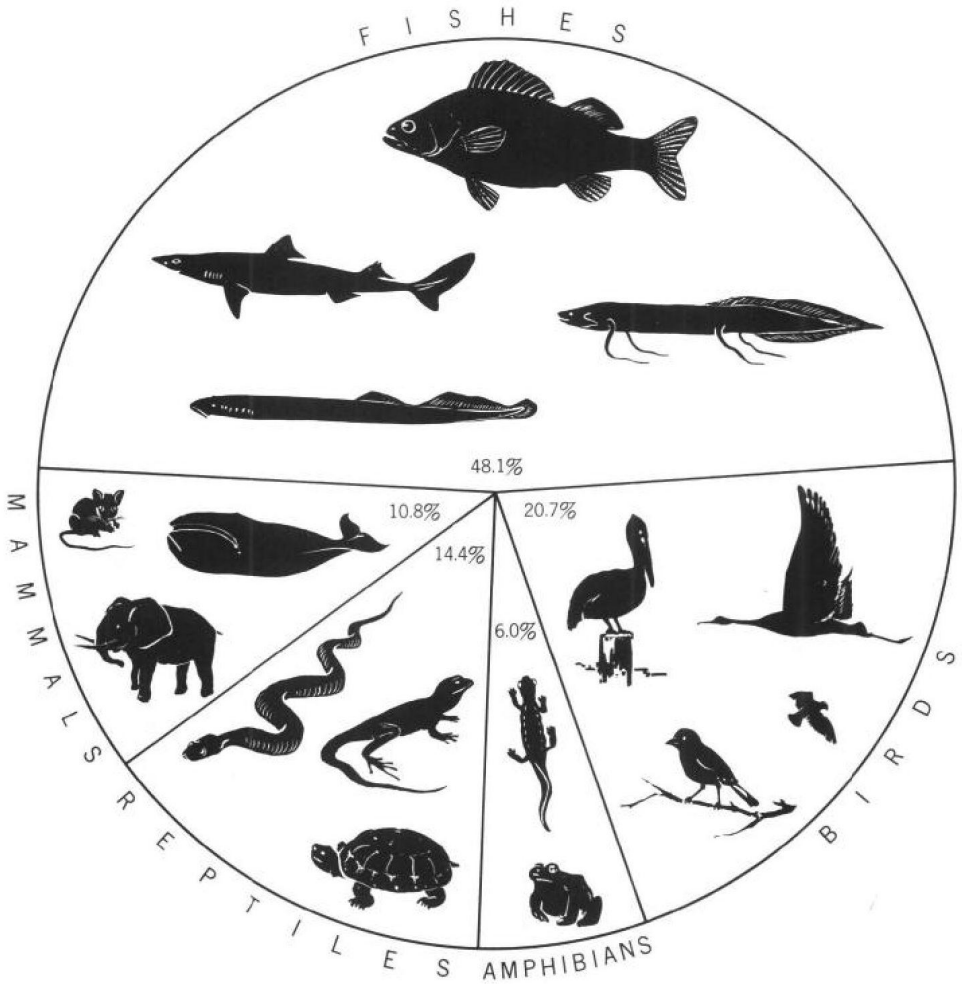

Fig. 1.1 Percentage composition by groups of the some 41,600 species of recent vertebrates.

FISH AS ANCESTORS TO MAN

According to evolutionary theory, which is based on evidence including fossils, comparative anatomy, embryology, and genetics, fishes have a distant place in the ancestry of man. Their presence on earth antedates man's ape-like ancestors by some 500 million years, and all other vertebrates by more than 100 million years. Without piscine ancestry, man might never have evolved. Many features of life ways and structure of man were originated or were already present aeons of time ago in fishy ancestors! These features include the ground plans and basic functions of the ten organ systems, including such

striking features as sight, internal fertilization, intrauterine nourishment (including placenta), live birth, and, presumably, learning and memory.

WHERE FISH LIVE

It is really no wonder that there are so many different kinds of fishes when their antiquity and the extent and variety of their habitat are considered. At present, more than 70 percent of the earth's surface is covered with water (Fig. 1.2). When the fish group was in its evolutionary youth, there was even more because much that is now land was ocean bottom then. Development of diversity of living conditions in water might be expected to accelerate the rate of speciation.

Fishes seem to have been able to keep pace with the development of variety in places of abode and now live almost wherever there is water, both on the surface and in the surface-connected subterranean waters. They occupy everything from Antarctic waters below freezing to hot springs of more than 40°C, and from soft, fresh water to water saltier than the seas. They are present in sunlit mountain streams so torrential that neither man nor dog can wade or swim them, and in waters so quiet, deep, and dark that they have never been inhabited by other vertebrates or thoroughly explored by man. Their vertical range of distribution exceeds that of any of the other vertebrates. Fishes range from approximately 5 km above sea level to some 11 km beneath it (Fig. 1.2).

HOW FISH LIVE

Water is highway, byway, communications medium, nursery, playground, school, room, bed, board, drink, toilet, and grave for a fish. All of the fishes' vital functions of feeding, digestion, assimilation, growth, responses to stimuli, and reproduction are dependent on water. For the fish, the most important aspects of water are dissolved oxygen, dissolved salts, light penetration, temperature, toxic substances, concentrations of disease organisms, and opportunity to escape enemies.

Although humans are able to absorb oxygen directly from air through the vascularized walls of the lungs, few fish have lungs or other devices for utilizing oxygen from air. Most fish, including those with lungs, depend mainly upon gills to extract oxygen dissolved in water. Fish cannot live long in a habitat rare or deficient in dissolved oxygen any more than humans can survive in the upper atmosphere or the space beyond unless they carry an oxygen supply with them.

The pasturage that the sea, lakes, and streams afford to fish depends

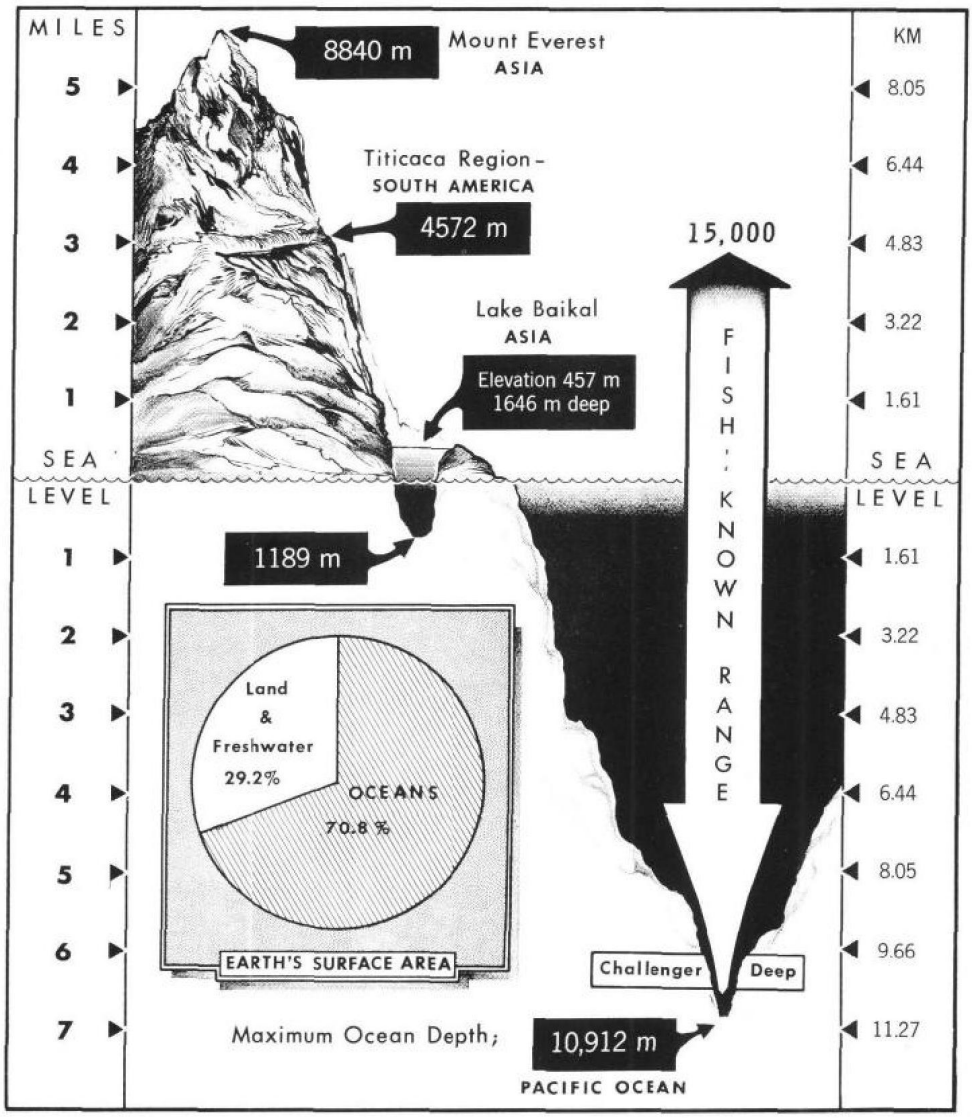

Fig. 1.2 Water area and vertical extent of fish distribution in relation to maximum relief on surface of the earth.

initially on the penetration of light into water, even as growth of grass on the open range relies upon the sun. The "grass" of the waters is microscopic plant life—diatoms and algae, collectively termed phytoplankton.

The beginning of the chain of life leading to fish production is generally in the bodies of the phytoplankters. They utilize light energy and dissolved carbon dioxide to manufacture organic matter that eventually becomes food

for fish. Besides providing energy for food production for all fishes, light is also known to trigger mechanisms of reproduction, growth, and many kinds of behavior, including that of feeding.

Unwanted materials such as toxins produced in nature and pollution from human activities are serious menaces to fish life. The aquatic habitat provides no places of escape from damaging substances in solution. The threat to fish of water-borne toxic materials is comparable to that of air-borne pollutants to human beings. Although fish are able to detect many such chemical contaminants, they are often unable to avoid them.

Like all animals, fishes have a very full complement of diseases with which to contend. Many of these are due to external agencies; others arise internally. From outside come viruses, fungi, bacteria, parasitic protozoans, worms, crustaceans, and lampreys. From within arise almost all the common organic and degenerative disorders that plague man himself. Included are cancer, rickets, degeneration of the liver, blindness, and a host of developmental anomalies such as Siamese twinning and spinal flexure. And even if not killed by a disease or disorder such as the foregoing, the fish must still survive periodic adverse chemical conditions in water, predators, and the capturing devices of fishermen.

HOW AND WHY FISH ARE STUDIED

Growth in knowledge of fishes has resulted from our lasting curiosity about nature and from our need for information concerning species used for commerce or recreation. At least ten centuries before Christ, the Chinese were trying to find out enough about fishes successfully to propagate them. Ancient Egyptians, Greeks, and Romans recorded observations on the varieties, habits, and qualities of various fishes. The symbol of the early Christian underground movement in the Catacombs of Rome was the fish.

The study of fishes (ichthyology) was hardly scientific until the eighteenth century in Europe. Since that time it has grown the world over along the following major lines:

Classification—the continuing, long-term effort to arrange all kinds of living and fossil fishes into various groups or taxa and to determine their natural relationships.

Anatomy—the structure of fishes from microscopic, embryological, and comparative points of view, including fossils where available and pertinent.

Evolution and genetics—the origins of fishes and the sequence and manner in which modern fishes evolved from previous ones and the mechanisms by which changes have come about; speciation; origin, transmission, and changes of the characters by which kinds of fishes are recognized.