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This series presents cutting-edge studies and accumulated wisdom from Japan and Asia, with titles addressing many of the aqua-bioscience and aquatic environment fields that form the basis of fishery science. Most of our food originates on land, but we cannot overlook food from the sea. Fishery science provides us with substantial knowledge – knowledge of living organisms in water, their habitats and environment; the knowledge to utilize these organisms; the political and administrative knowledge to organize social activities and systems to distribute fishery products; and a technical and engineering knowledge of ships, fishing equipment, sea ports and harbors. The discipline covers a huge variety of subjects, and each subject includes basic and applicative aspects that are both related and essential to one another. For fishery science to prosper, none of them can be ignored. As a country with a long history of fish eating, Japan has created unique, world-class cultures and technologies in fisheries, aquaculture, aquatic environments, seafood science, and other fishery-related sciences. Through carefully selected state-of-the-art works on topics in the field of fishery science, this series aims to contribute to the development of fishery and the welfare of people around the globe. This is an official book series of the Japanese Society of Fisheries Science.

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Application of Recirculating Aquaculture Systems in Japan

Springer

JSFS

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Foreword to the Series

We all have to survive, and most of our food originates from that grown on land, but we can't overlook food from the sea. We catch creatures living in the water ecosystem by fishing techniques and eat them raw or cooked. That whole process and related activities are collectively called "fishery," and fishery is supported by fishery science that relates to a vast range of fields.

Fishery science brings us much knowledge—biological knowledge of the life in water; knowledge about their habitats and environment; knowledge to utilize these lives; political and administrative knowledge to organize social activities and system to distribute fishery products; technical and engineering knowledge of ships, fishing equipment, seaports, and harbors; and so on. It covers a great variety of subjects, and each subject contains both basic and applicative aspects relating to and essential to one another. To have fishery science prosper in human society, none of them can be ignored.

This series includes many of the aqua-bioscience fields and aquatic environment fields as the base of fishery science.

In this Fisheries Science Series, we provide you with carefully selected up-todate topics of excellent works in the fields of fishery science. We hope our series can contribute to the development of fishery and the welfare of people worldwide.

Tokyo, Japan
July 2017

Katsumi Aida
Series Editor-in-Chief

Preface

In 2006, a shocking report was published in *Science* that stated that the world's fish stocks would be depleted by 2048. Other reports followed on the declining populations of bluefin tuna, eels, and other fish species one after the other. The prospect of disappearing fish stocks took on a realistic tone.

On the other hand, the global human population is expected to surpass 9 billion in 2050, leading concerned experts to warn us of an imminent food supply crisis. In such a situation, demand for fisheries products has been growing in Europe, North America, and East Asia, with the annual per capita consumption of seafood reaching 20 kg in 2014. As an increasing amount of protein is taken from the sea, fish farming has been developing so much as to almost surpass wild fisheries as the main sector within the fishing industry, accounting for 44% of the industry's total output in 2014.

However, aquaculture poses many problems that must be solved. For example, the massive importation of cultured shrimps and other marine products from developing countries into Japan causes coastal environmental deterioration due to the felling of mangrove necessitated by aquaculture. In Japanese coastal areas, self-contamination has been spreading due to net cage fish culture. The document titled "The Future We Want," adopted at the United Nations Conference on Sustainable Development (UNCSD or "Rio+20") held in June 2012, states in its section on agriculture, forestry, and fisheries that sustainable agricultural production and productivity must be boosted in consideration of diverse agricultural practices in the respective countries. Along this line of thought, we believe that initiatives for resource-recycling and a more sustainable growth-oriented culture of aquatic resources will become far more important in the future.

Unlike in the West, aquaculture in Japan is mainly conducted on the sea surface. In other words, it is mariculture that is particularly active in Japan. The mariculture of yellowtail *Seriola quinqueradiata*, red sea bream *Pagrus major*, and coho salmon *Oncorhynchus kisutch*, which accounts for almost 90% of the country's total mariculture output, is entirely net cage-based, while a land-based running water system is used for Japanese flounder *Paralichthys olivaceus* and kuruma

prawn *Marsupenaeus japonicus*. Since these farming methods all involve feeding, they tend to cause red tide and a deterioration of water quality in fish farms in inner bays and surrounding coastal areas. It is therefore necessary to prevent eutrophication and the accumulation of sediment in these coastal areas. The preventive measures that have been taken thus far include water quality control through the adjustment of population density within net cages and the improvement of feed forms and feeding methods so as to reduce feed remnants and undigested feed. In more recent years, active research has been carried out on integrated fish farming, in which nitrogen and phosphorus released by fish are used for the culture of algae, and closed recirculating land-based aquaculture systems, in which fish excrement is not released into the sea.

This book introduces the application of recirculating aquaculture systems in Japan from the viewpoint of bioscience, in the hope of contributing to the further development of aquaculture, whose output has been growing on a global scale. The book also outlines problems to be solved for future generalization, economic and business aspects of land-based aquaculture, as well as business opportunities. In concrete terms, closed recirculating aquaculture systems are outlined, and examples of their application to various marine fish types are presented. Also discussed are ecologically integrated fish farming, aquaponics, and closed ecological recirculating aquaculture systems, in which fish excrement is put to effective use, and systems for the eventual industrialization of closed recirculating land-based fish farming.

In July 2013, the Fisheries Agency of Japan organized a meeting on the future of fish farming, where proposals were made regarding land-based aquaculture. The meeting concluded that fish farmers were expected to actively engage in land-based aquaculture because, as stated in the Basic Plan for Fisheries, it is useful in diversifying fish farms, promoting new local industries in fishing villages, and creating jobs for which specialist knowledge and expertise may be utilized. Accordingly, it is expected that land-based aquaculture will be promoted as a national policy.

It is my hope that this book will serve not only as a textbook for undergraduate and postgraduate students but also as a useful reference for corporate researchers considering the fish farming business. I would like to express my deep gratitude to the members of the editing committee, who carefully reviewed my manuscript, and the staffs at the Japanese Society of Fisheries Science and Springer Japan for their kind cooperation regarding publication. I dedicate this book to my beloved wife, “Le Vien (Eri),” who has supported me for 40 years.

Tokyo, Japan Toshio Takeuchi
August 2017

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