FOREWORD

A Bering Sea Working Group was established at the first North Pacific Marine Science Organization (PICES) Annual Meeting, in 1992. The group is interdisciplinary as well as international, and its activities have included identification of key unanswered questions (see Appendix) and organization of a Bering Sea Symposium held in October 1995 during the Fourth Annual Meeting of PICES, in Qingdao, China. An early charge was to initiate preparation of a book reviewing present knowledge of the climatology, oceanography, and biology of the Bering Sea.

Recently, several substantial Bering Sea volumes have appeared. Russian papers edited by Kotenev and Sapozhnikov (I 995) are concerned with the Bering Sea ecosystem, and Russian investigations are also the basis for Mathisen and Coyle's (1996) compilation of papers on ecology of the Bering Sea. A different sort of review is found in the Committee on the Bering Sea Ecosystem's (1996) analysis of the state of the Bering Sea ecosystem.

Each of these publications is specialized, in purpose, geography, nationality, or scientific discipline. Changes in the political relations among countries working in the Bering Sea, and the advent of a regional international scientific organization, PICES, have now provided the opportunity to bring the findings of scientists of all disciplines and countries together in a contemporary synthesis of the oceanography of this region.

Vast as the Bering Sea is (2.3 million km^2 according to Fairbridge [1966]), it is a convenient microcosm for such a synthesis. Although the basin is semi-enclosed, in a geographical sense, it actively exchanges with the Arctic Ocean and the North Pacific. Atmospheric forcing is on a large scale, with the Aleutian Low playing an important role. Biological conditions reflect the oceanic forcing, with tides being particularly important on the continental shelf. The ecosystems are complex like those of other high latitude regions, and are enormously productive of finfish and shellfish, along with marine mammals and seabirds. It seems likely that even before commercial harvesting of living resources began, the resident populations exhibited large fluctuations in distribution and abundance, resulting just from the physical forcing and the internal dynamics of the ecosystems.

One reason for the recent interest in the Bering Sea is the perception that commercial fisheries, among the largest in the world, have seriously damaged Bering Sea ecosystems. Evidence cited for this damage includes declines in several conspicuous populations, including king crab, Steller sea lions, and several species of seabirds. There is a popular sentiment that all human activities in favored ecosystems are inherently bad, and fishery biologists have traditionally assumed that essentially all changes, but especially decreases, in fish stocks have resulted from human activity.

Meanwhile, evidence is accumulating that climate variations on decadal to century scales have identifiable ecosystem effects and that interdecadal changes such as the 1976 regime shift have been associated with major changes in fish stocks in the North Pacific. For example, a recent study (Wyllie-Echeverria 1996) showed that the coverage of winter sea ice in the Bering Sea, which correlates with the distribution of Pollock the following summer, was significantly different before and after the late 1970s. Variations in ocean circulation and mixing, driven by the atmosphere, may affect ecosystems either from the bottom up or the top down, and the linkages are as yet poorly understood. At the same time, it is obvious that ecosystems are also forced by human predation, and our skill at sorting out the relative importance of these kinds of forcing in any given case is limited.

Such questions led PICES in 1993 to initiate planning for a program called Climate Change and Carrying Capacity (CCCC), as part of an international program on Global Ocean Ecosystem Dynamics (GLOBEC). The goal of CCCC is to understand the effect of climate variations on marine ecosystems. A comparable effort is also needed to establish the effect of fishing on these ecosystems. Ultimately, predicting the response of climate and human forcing on any specific marine populations will depend on a much better understanding of these systems than we now have. For any given region, such as the Bering Sea, a synthesis of existing knowledge such as the present volume, is a key to the eventual achievement of that predictive capability.

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PREFACE

Dr. Warren Wooster mentioned in the foreword that this book was originally conceived in the PICES Bering Sea Working Group chaired by Dr. Al Tyier. The last review (Hood and Calder 1981) was outdated, and because of the current interests in Bering Sea resources the working group felt that a timely review was needed. This book reviews past publications on the Bering Sea, looks at the type and direction of present research in and adjacent to the Bering Sea, and makes suggestions for future studies. The intent is to summarize the Current body of work on the Bering Sea as a resource guide to scientists, managers, and others from all nations working in the Bering Sea and similar ecosystems.

The Bering Sea is one of the most productive ecosystems in the world. It is at least a seasonal home to some of the largest marine invertebrate, fish, bird, and mammal populations among the world's seas. The North Pacific Ocean and Bering Sea are not only one of the most productive ocean regions in the world, they also support many of the world's largest populations of groundfish, salmon, and crab. For example, large-scale commercial fisheries for groundfish in Alaska waters are now a major industry with 1992 landings totaling almost 2 million metric tons generating ex-vessel revenues of over $600 million. When the landings and values generated by fisheries for Pacific halibut, crabs, and salmon are also considered, the commercial fisheries off Alaska alone generate several billion dollars each year, as well as millions of metric tons of protein for the world.

The resources of the Bering Sea also provide for the subsistence needs of residents of the Bering Sea region. Food, clothing, cultural and religious artifacts, handicraft items, and economically valuable products have been taken from the Bering Sea for thousands of years by inhabitants of the Bering Sea coast. These subsistence resources are essential today to the livelihood of American and Russian Natives and other residents of Bering Sea coastal communities.

The U.S. National Research Council recently established the Committee on the Bering Sea Ecosystem and charged it with (1) evaluating the environmental factors and ecological relationships that control the Bering Sea food web, (2) evaluating the probable cause and effects of observed population fluctuations, (3) estimating historical population dynamics of marine mammals and birds, and commercially important species, (4) evaluating historical records of commercial fisheries, and (5) evaluating the relationship between biological resources and subsistence cultures of indigenous people. Some of the recommendations for research and management within the NRC report are relevant to this book. They include recommendations to (1) improve coordination of the many institutions and groups conducting studies or utilizing the resources of the Bering Sea, (2) adopt a broader ecosystem perspective for both scientific research and management of Bering Sea resources, and (3) conduct research on the structure of the ecosystem (with emphasis on the cause of pollock population dynamics and the role of sea ice in structuring the ecosystem). Many of these recommendations are included here.

Dynamics of the Bering Sea has four parts-the first part has chapters in particular disciplines, the second has chapters reviewing major pro- grams formerly conducted in the Bering Sea, third is a concluding chapter summarizing the entire volume, and last is an appendix on research topics that need more study. Within each of the three discipline area sections (Physical Dynamics, Chemical Distribution and Dynamics, and Biological

Dynamics), the first chapter is a review and the following assortment of chapters report specific research projects to provide a glimpse at the kind of studies currently under way in PICES member nations.

After receiving guidance on the general topics and framework for the chapters from us, the section editors selected the topics to be addressed in their sections, chose authors to write on the topics, solicited the papers, and arranged for peer review. Section editors for Physical Dynamics are Dr. S. Gladychev, Pacific Oceanographic Institute, Russian Academy of Sciences of the Far East, Vladivostok, Russia; and Dr. J. Schumaker, PMEL, Seattle, WA, U.S.A. Section editors for Chemical Distributions and Dynamics are Dr. T. Whitledge, University of Alaska Fairbanks, Fairbanks, AK, U.S.A. (formerly at the University of Texas); Dr. Y. Maita, Hokkaido University, Hakodate, Japan; and Dr. V. Sapozhnikov, VNIRO, Moscow, Russia. Section editors for Biological Dynamics are Dr. R. Francis, University of Washington, Seattle, WA, U.S.A.; and Dr. T. Ikeda, Hokkaido University, Hakodate, Japan.

Some highlights of the book follow:

1. The existence of interannual and decadal changes in biological resources and variability of oceanic conditions affected by meteorological and climatic changes.
2. The magnitude of the variations in biological resources caused by climate change is as large as, or even exceeds, those caused by human activities (fishing, etc.); however, our knowledge of the processes and mechanisms on those relationships are qualitative, fragmentary, and scarce.
3. An attempt is made to show a network of physical, chemical, and biological relations in the Bering Sea ecosystem in an effort to guide and enhance future investigations.
4. Cooperative research among all nations is needed to attain needed answers to complex ecosystem questions, which should be the ultimate goal of future efforts.

We wish to acknowledge the financial support and encouragement offered by PICES, particularly Drs. Warren Wooster and Doug McKone, in the publication of this volume. The National Marine Mammal Laboratory and Alaska Fisheries Science Center also provided financial and logistical assistance. We thank members of the Bering Sea Working Group for their involvement and guidance in this project. We gladly recognize Sue Keller and Carol Kaynor of the University of Alaska Sea Grant for their expert production of the book, Ron Dearborn for supporting the publishing effort, and Dave Brenner for designing the cover. We wish to give special recognition to Rebecca Paulson for her editorial support and considerable time and expertise in the management of the in-house preparation of the book. Lastly, we wish to thank the authors and their host institutions for their participation and enthusiasm, which led to the completion of this project.

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