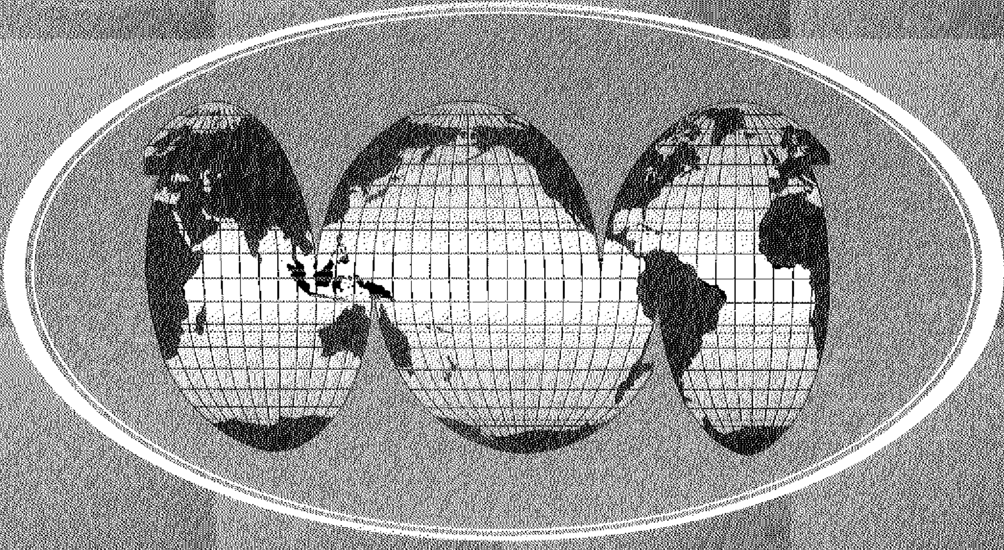


Our Common Shores & Our Common Challenge

Environmental Protection of the Pacific

Proceedings of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents

Our Common Shores & Our Common Challenge

Environmental Protection of the Pacific

Proceedings of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents

Anchorage, Alaska
September 1993

Edited by
David G. Shaw

Copies of this book are available from

Alaska Sea Grant College Program

University of Alaska Fairbanks

P.O. Box 755040

Fairbanks, AK 99775-5040

Price: $20

Acknowledgments
The Fourth Symposium of the Conference of Asian and Pan-Pacific University Presidents gratefully acknowledges financial assistance from the Japan Foundation Center for Global Partnership, the University of Alaska, and Alaska Pacific University.

Symposium Program Committee
David G. Shaw, Chair
Syun-Ichi Akasofu
John J. Goering
C. Peter McRoy
William J. Stringer
Albert V. Tyler

Symposium Coordinators
Nancy Bachner
Maggie Billington

Conference Secretariat
Toshibumi Sakata

Conference Secretary-General
Matsuro Matsumae

Conference Steering Committee
John A. DiBaggio
Huang Da
Jerome B. Komisar
Vladimir I. Kurilov
Tatsuro Matsumae
Victor A. Sadovnichii
David W. Strangway

Conference Liaison Office
Mamoru Kawazoe
Hirohisa Uchida
Kiyoshi Yamada
Takashi Watanabe
Teiko Yokohata

Credits
This proceedings was published by the University of Alaska Sea Grant College Program, Fairbanks, Alaska. Cover design by Dixon Jones, University of Alaska Fairbanks; map artwork courtesy of National Ocean Survey, National Oceanic and Atmospheric Administration. Editing and pre-press production by Rae Jones, Fifth House Publication Arts, Fairbanks, Alaska. Project coordination and editing by Sue Keller, Alaska Sea Grant College Program.

Citation for this volume is: D.G. Shaw (Editor) 1994. Proceedings of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents. Alaska Sea Grant College Program, University of Alaska Fairbanks.

Elmer E. Rasmuson Library Cataloging-in-Publication Data

International Symposium of the Conference of Asian and Pan-Pacific University Presidents
(4th : 1993 : Anchorage, Alaska)
Our common shores and our common challenge : environmental protection of the Pacific : proceedings of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents, Anchorage, Alaska, September 1993.

1. Environmental policy—Pacific Area—Congresses. 2. Pacific Area—Congresses. 3. Pollution —Environmental aspects—Pacific Area—Congresses. 4. Coastal ecology—Pacific Area—Congresses. 5. Fishery management—Pacific Area—Congresses. I. Shaw, D. G. (David George), 1945– . II. Title. III. Title: Proceedings of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents.

GF798.097 1993

ISBN 1–56612–027–6

Table of Contents

Foreword vii
David G. Shaw

Anchorage Declaration ix

Remarks

Welcome 1
Jerome B. Komisar

Opening Comments 3
Tatsuro Matsumae

1995 Symposium 4
Paul LeBlond

Conclusion 4
Jerome B. Komisar

Resources from the Pacific

Stewardship and Sustainability of Pacific Fishery Resources: The Need for Critical Insight and an Encyclopedia of Ignorance 5
Tony Pitcher

Establishing Rapport Between Indigenous Coastal Cultures and the Western Scientific Community 29
Larry Merculieff

Economics of Resource Use: A Bioeconomic Analysis of the Pacific Halibut Fishery 37
Keith R. Criddle

Pollution of the Pacific

Problems of Radioactive Waste Dumped in the Seas Surrounding Russian Territory 53
Yury Kazakov

Pollution of the Coastal Zone in the Japan Inland Sea 69
Shiro Okabe

Tracking the Flow of Waste Materials in the Pacific Ocean 87
Toshibumi Sakata, Haruhisa Shimoda, and Kohei Cho

Sustaining the Pacific

The Difficulty of Enforcing Environmental Protection Legislation 93
Vladimir Kurilov

The Role of Data Interpretation 95
Kent Bridges

Open Ecological University: One Approach to a Modern Environmental Education 103
Valery Petrosyan

North Pacific Ecosystems: A PICES Priority 111
Warren S. Wooster

Working Group Reports 117

Marine Environmental Education
Sustainability of the Pacific
Coastal and High Seas Monitoring

Poster Session Abstracts

Ecological Problems and Monitoring of the Far Eastern Seas 119
Peter F. Brovko

The Coastal Ecosystems of the ASEAN Region: A Vanishing Frontier? 119
Miguel D. Fortes

Environmental Influences on Salmon Migration in the Northeast Pacific 120
Paul LeBlond and Keith A. Thomson

Spring Sea Ice Conditions from SAR Images Near the Alaska Coast of the Chukchi 120
Fucheng Li, John Kelley, and Eriko Uematsu

China's Environmental Problems and Fudan University's Research Programs in the Environmental Sciences 121
Xu Ming-zhi

Pollution of the Coastal Zone in the Japan Inland Sea 123
Shiro Okabe

The Role of Data Acquisition from Satellite-tracked Drifting Buoys 124
Toshibumi Sakata

Biochemical Monitoring of Bowhead Whales Caught off Barrow, Alaska: Serum Protein and PCB Levels 125
Cynthia M. Simons, Beverly Johnson, Lawrence K. Duffy, Eric Follman, and John Kelley

Underground Nuclear Explosions and Global Nuclear Fallout: Impact on Yakutia 125
V.E. Stepanov, S.I. Degtyaryev, A.A. Alekseev, Z.E. Petrov, G.I. Borisov, and A.V. Stepanov

Natural and Anthropic Impacts and Disturbances on the Central and Southern Coasts of Chile 126
José Stuardo

Analysis of Drifting Buoy Experiments in the North Pacific Ocean 127
Yasuhiro Sugimori, Akira Nakamura, Masao Fukasawa, Toshifumi Sakata, Haruhisa Shimoda, and Kohei Cho

National Parks of Yakutia? 128
O.N. Tolstikhin

Sustainable Development for the Pacific Region: The Contribution of UNU Research Programs 129
Juha I. Uitto

A Floating International University of Marine Science in the Tropics 129
Leandro A. Viloria

The Department of Marine Sciences at Chulalongkorn University 130
Supachai Yavaprabhas

Participants 131

Foreword: Our Common Shores and Our Common Challenge

Over the last century industrial waste, urban runoff, sewage effluent, oil spills, overfishing, unwise coastal development, and other similar factors have placed the Pacific Ocean and the species and ecosystems it supports under unprecedented pressure. Most evident in coastal waters, environmental degradation has eroded the ocean's ability to contribute to the quality of life. Further degradation of either coastal waters or the open ocean is a matter of serious concern.

Because the Pacific Ocean is simultaneously a vital part of natural cycles that sustain all living things, an important supplier of resources directly consumed by humans, and a repository of wastes increasingly produced by all societies, it is imperative that humans safeguard and preserve the health of the ocean. Any significant decline in the health of the Pacific Ocean would present a severe challenge to the highest aspirations of the people of the region, and to the global ecosystem.

The nations of the Pacific region vary in history, in culture, in political structure, and in economic development. They share, however, a deep desire for increasing quality of life including economic development and improved standards of living compatible with the sustainability of the marine environment. That quest—and the pressure of increasing populations—will define much of the future of the environment, particularly the marine environment.

The interplay of development and environmental protection is incredibly complex, so complex that it severely tests our logic, our compassion, and our endurance. It is also a dynamic of supreme importance, for in our relentless search for betterment, we have put our very planet at risk.

The challenge is to simultaneously use and conserve our planet's wealth in ways that can be sustained both ecologically and politically. Preserving the health of the Pacific Ocean will require careful evaluation of the effectiveness of the institutions monitoring and protecting the region. It seems probable that such institutions are at least in part dysfunctional and that the combined efforts of natural scientists, policy analysts, experts in international law, environmental economists, and other scholars reflecting the region's cultural diversity are needed in the search for sustainable solutions.

In 1985 the late Shigeyoshi Matsumae, President of Tokai University, and the late Jean Mayer, President of Tufts University in Massachusetts, agreed that scholars must confer on issues such as exchange programs, cooperative projects, and curricula in order to promote world peace. Their commitment to this ideal led to a series of meetings of University presidents, research institute directors, scholars, and academicians devoted to international efforts to increase harmony among peoples and with the natural systems that sustain the Pacific region. Three major meetings have previously been held:

- Toward a More Active Role for Peace and Stability, 1987, Tokai University, Tokyo
- For Peace and Prosperity in the Asian Pacific Region, 1989, Tokai University, Tokyo
- Global Environmental Protection and the Future of Humanity, 1991, Far Eastern State University, Vladivostok

Each of these meetings brought together an international group of intellectual leaders to address issues vital to mankind and each resulted in a Declaration which encapsulates the concerns, the hopes, and the plans of the participants. The goals set forth are high and some of them remain beyond human reach. This is appropriate. Presidents Matsumae and Mayer were wise and far sighted; they have focused attention on the central problems of our times. Much work remains to be done.

The Fourth Symposium, with the theme Our Common Shores and Our Common Challenge: Environmental Protection of the Pacific, continued to work toward the goals set by Presidents Matsumae and Mayer, and brought nearer by the three preceding symposia. However, as at each meeting, new elements are being added. This was the first meeting of the Conference of Asian and Pan-Pacific University Presidents to be held on the North American continent. This venue recognized unity of concern by all Pacific Rim nations for our common sea and symbolized resolve of scholars from throughout the region to address important issues. The Fourth Symposium also added a strong technical and scholarly agenda to the deliberations of University Presidents in recognition of the needs for further research and for technical and institutional changes at the international level.

These proceedings provide a record of the hopes, ideas, and aspirations of the participating scholars. It is the hope of the Fourth Symposium organizers that this volume will contribute to the realization of those hopes and aspirations for the benefit of all peoples of the Pacific region.

David G. Shaw
Chair, Program Committee
Fourth Symposium
November 1994

Anchorage Declaration, 1993
The Conference of Asian and Pan-Pacific University Presidents

We, university presidents, institute directors, and scholars from the Pacific region, have gathered in Anchorage, Alaska on 12-15 September, 1993 for an international symposium with the theme, Our Common Shores and Our Common Challenge: Environmental Protection of the Pacific. On this occasion we reaffirm our belief in the value of the Conference of Asian and Pan-Pacific University Presidents and its schedule of biennial meetings. We thank Tokai University for maintaining the General Liaison Office and recommend that this essential function be continued. We further thank President Komisar and the University of Alaska for hosting this productive and pleasant meeting in Anchorage, Alaska. We are pleased to accept the offer of The University of British Columbia to host our next major meeting in 1995.

We have considered the possible environmental consequences of current trends in human activities and discussed actions that scholars can take to promote sustainable use of the Pacific environment for the mutual and equitable benefit of present and future generations. The participants have agreed on the following points as reflecting the present situation:

1. Because the Pacific Ocean is simultaneously a vital part of natural cycles that sustain all living things and an important supplier of resources consumed by humans, it is imperative that humans protect and sustain the Pacific environment.
2. While the nations of the Pacific region vary in history, culture, political structure, and economic development, all share the desire for increasing the quality of life and improving standards of living.
3. Because of continuing increases in the human population and increases in development in many countries, it can no longer be assumed that natural processes and traditional human institutions are adequate to protect and sustain the Pacific environment.
4. University scholars in the natural sciences, economics, policy analysis, international law, and other fields have a special obligation to understand the processes that regulate the environment and its living resources, to search for sustainable pathways of human development, and to teach others about these matters.

In response to these points the participants make the following recommendations and agree to undertake the following specific activities and projects.

1. We recommend that the members of the Conference of Asian and Pan-Pacific University Presidents work within their respective nations to promote general understanding of the importance of ecological and developmental issues and to increase the levels of research and analysis in these fields.
2. We recommend that the participating universities and institutes share with each other the responsibilities of academic leadership by increasing the ties among their scientific centers through personal contacts, the exchange of faculty, researchers, and students; the sharing of research equipment and laboratory facilities; and the exchange of research findings and questions.
3. We recommend that the academic research centers of the participating members coordinate, as far as possible, their research plans so as to effectively challenge the scientific, technological, and social questions facing the nations of the Pacific.
4. We propose to expand the project for satellite monitoring of the Pacific Ocean environment on the basis of the recommendations made at the third meeting of our conference in Vladivostok

in 1991 by taking advantage of the launch of new generations of environmental satellites including ERS-1, JERS, TIROS/NOAA series, ADEOS-1, ADEOS-2, Sea Star, and Radarsat. We further propose that the Kumamoto Station of the Tokai Space Information Center of Tokai University under the leadership of Prof. T. Sakata and the Alaska SAR Facility of the Geophysical Institute of the University of Alaska Fairbanks under the leadership of Prof. S.I. Akasofu coordinate this project.

5. We propose to initiate a project to measure the kinds and amounts of marine debris including plastic in the Pacific Ocean. The first activity of this project will be to coordinate beach surveys by interested participants. Prof. D. Shaw at the University of Alaska Fairbanks will coordinate this project.
6. We propose that a working party be established by interested participating universities to formulate a plan for joint research dealing with the accumulation of toxins in marine food webs. Particular emphasis will be given to toxins that may lead to chronic neurologic, immunologic, and endocrine disease in humans. Other aspects of human environmental toxicology such as genetic effects of radioisotopes from the marine environment may be examined by focusing on nucleic acid repair mechanisms. Prof. C. Reinisch at Tufts University will lead this working party.
7. We propose that a working party be established by interested participating universities to formulate plans for projects in marine environmental education. Projects to be considered include a ship-based marine education and research program, student exchange programs, and other activities that improve environmental education and promote awareness of cultural differences in environmental perspectives. Prof. V. Petrosyan at Moscow State University and Prof. J. Stuardo at the Universidad de Concepción will lead this working party.
8. We propose that a scientific workshop be held in 1994 to discuss progress and future prospects of the scientific projects of the Conference. The Conference is pleased to accept the offer of Tokai University to host this workshop at the Tokai Pacific Center in Honolulu, Hawaii.
9. We accept the attached Working Group Reports as representing the considered judgment of the participants in the Anchorage Symposium.

Welcome

Jerome B. Komisar
President, University of Alaska
Fairbanks, Alaska, U.S.A.

It is a pleasure to welcome you to Alaska and to the Fourth Symposium of the Conference of Asian and Pan-Pacific University Presidents. The University of Alaska and the people of this state are greatly honored to have your company.

By population, Alaska is next to the smallest state in the United States; by geographic area, it is by far the largest. It is enormously endowed with natural resources in its oceans and rivers, in gold and oil and coal; in clean water and in clean air; most of all, in the energy and creativity of its people. I hope that during the next few days, those of you who are visiting Alaska for the first time, as well as those who live here, will be able to take at least a few minutes to experience the beauty of Alaska, enjoy the friendliness of its people and gather a sense of their hopes and their visions.

The Conference of Asian and Pan-Pacific University Presidents began in the wisdom and discussions of two renowned university presidents, the late Shigeyoshi Matsumae, then President of Tokai University Educational System, and the late Jean Mayer, who at the time was President of Tufts University. The objective of the conference is best heard in the words of Shigeyoshi Matsumae:

> Both as educators as well as intellectuals, the university presidents and heads of their research institutes should have a strong sense of responsibility for their mission in maintaining peace, further developing and stabilizing the situation of the world, and in a willingness to play more positive roles in the accomplishment of such goals.

The first meeting of the conference took place in 1987 in Tokyo. The topic was Toward a More Active Role for Peace and Stability. The second gathering, held in Tokyo in 1989, was built around the theme For the Peace and Prosperity in the Asian Pacific Region. The third meeting, held in Vladivostok, 1991, explored the topic Global Environmental Protection and the Future of Humanity. The symposium we begin today, Our Common Shores and Our Common Challenge: Environmental Protection of the Pacific, continues the tradition established by Dr. Matsumae. It concentrates on the science we will need for survival, but the political and social issues that cloud the future will be present in our conversations and in our thinking.

The world has changed considerably since Dr. Matsumae's and Dr. Mayer's discussions in 1985. Nations and economies have restructured, and trade routes and military challenges have altered in ways that few would have predicted just eight short years ago. Just think of the unbelievable ceremony which took place this morning, and just ended a few minutes ago with the signing of a peace declaration by the state of Israel and the PLO.

The most radical change has been an almost universal acceptance of the vitality of free markets, and the productive efficiency of economic freedom. But ironically, just as people living in countries first experimenting with free markets are building their aspirations on the benefits of competition, young people who have been raised in competitive economies in Germany and France, England and Italy, the United States and Japan, are growing more deeply worried about their futures. In the West and East, in long-time capitalist nations and in the new ventures, people—young and old—have lost faith in the ability of the current generation of political leaders to lead. It is as if the end of the Soviet empire has forcefully reminded us that societies, too, are mortal, and civilizations fragile.

Our planet's compelling problems, of course, transcend theories of economic systems and political order. As we end some of the political debates that have raged through this century, intellectual, religious, and military conflicts are flaring up. The most destructive and intractable human paradoxes continue. How do we, as nations, come to grips with the vast differences existing among us as to national wealth and economic prospects? How do we deal with domestic and international angers, with irrational rivalries and prejudices? What do we do to fuel our economies and simultaneously keep the air breathable and our oceans full of life? And what of health care and education, of falling real incomes, of population explosions, and famine and disease and pestilence?

Over the next three days these issues will lie beneath our concerns about the health of the Pacific Ocean. This gathering is part of an essential process, discovering the vocabulary, theories, and facts necessary for the exploration of basic international issues and the discovery of internationally acceptable solutions.

Welcome, all of you, to this conference and to our collective work.

Thank you.

Opening Comments

Tatsuro Matsumae
President, Tokai University Educational System
Tokyo, Japan

First of all, as the Secretary-General of the Asian Pacific University Presidents Conference, I would like to thank President Komisar, Professor David Shaw, Professor Shun-Ichi Akasofu and the other members of the Program Committee for their outstanding efforts to hold this symposium at Anchorage, Alaska. I am grateful to the University of Alaska for hosting the fourth conference, Our Common Shores and Our Common Challenge: Environmental Protection of the Pacific.

Let me explain briefly the background of this series of meetings. In 1985, the late Dr. Jean Mayer, the former President of Tufts University, and the late Dr. Shigeyoshi Matsumae, the former President of the Tokai University Educational System, agreed that presidents and directors of universities and research institutions should have opportunities to exchange their opinions and ideas as educators and scholars to promote international cooperation toward a stable and peaceful world. In consequence, a meeting was held the following year with the presidents of Tufts University, People's University of China (now Renmin University of China), Novosibirsk University, Far Eastern Research Institute of USSR Academy of Sciences (now the Russian Academy of Sciences) and Tokai University. Participants exchanged ideas and agreed to form a Conference of Asian and Pacific University Presidents and Directors of Research Institutions.

In 1987, the first conference was organized in Tokyo by Tokai University under the theme of Toward a More Active Role for Peace and Stability.

The second one was held in 1989 in Tokyo by Tokai University with the subject of For Peace and Prosperity in the Asian Pacific Region.

The third conference was organized by Far Eastern State University at Vladivostok in 1991 and titled Global Environmental Protection and Future of Humanity.

In 1992, the Marine Environmental Project: North Pacific Meeting, a workshop based on the Vladivostok Declaration, was held in Honolulu, with specialists from University of Alaska, University of Hawaii, University of British Columbia and Tokai University.

I am sure our meetings will bring many fruitful results and will be highly regarded by the world.

When we held our first Conference in 1987, the world was amid the cold war. The cold war is now over. Today, in Washington, a treaty to bring about Peace to the Middle East was signed. Now is the time for us to engage ourselves full force with a new task of concern to all humans: sustaining the health of the global environment.

One of our aims in this symposium is to discuss the possibility of international collaboration for environmental protection of the Pacific Ocean. Discussions will also be held on themes such as Resources of the Pacific, Pollution of the Pacific, and Sustaining the Pacific. I fervently hope that our discussions result in many ideas and proposals for collaboration.

It is meaningful to deal with the issues of marine pollution and the environmental condition of the northern Pacific Ocean in this meeting, which is attended by representatives from universities and research institutions in the Pan-Pacific area. Pollution in the area is rapidly increasing. It is urgent that we examine the area by collecting data by means of drifting buoys and satellite monitoring which call for international collaboration.

As educators and scholars, we must make a concerted effort toward the peace and prosperity of human beings, transcending the boundaries of cultures and countries.

I hope that active discussions for the future of the Pacific Ocean covering the fields of education, sociology, economics, and science and technology take place here. I hope actual actions for sustaining the environment and resources of the Pacific will follow.

In concluding my remarks, I wish all the participants a fruitful meeting.

Thank you.

1995 Symposium

Paul LeBlond
University of British Columbia
Vancouver, British Columbia, Canada

Thank you very much for the opportunity to express to you the best wishes of Dr. Stangway of the University of British Columbia. Dr. Stangway could not be here; however, he asked me to express to you his continued support of the principles and the philosophy of this conference, and his continued appreciation for the leadership provided by Dr. Matsumae and his colleagues at Tokai University. I was also very pleased that the steering committee has accepted the invitation which was offered by the University of British Columbia to host the next meeting in 1995, and after the superb organization and the stimulating talks that we've heard today, we have certainly a task ahead of us to come up to the standards put up by Dr. Komisar and his colleagues at the University of Alaska.

Thank you.

Conclusion

Jerome B. Komisar
President, University of Alaska
Fairbanks, Alaska, U.S.A.

I'd like to thank all of you who have participated in the conference. It has been an exceptional meeting.

The secret of the Asian and Pan-Pacific Presidents' Conference is that it really doesn't end at the end of a meeting. Each meeting is really a beginning because each meeting has been used to bring people together to begin research projects, not to conclude them; to begin discussions rather than to end them. If anything has been accomplished over the last three days, it has been to outline an agenda that is far larger than we will be able to achieve over the next few years, but which has the ingredients of progress deeply embedded in it.

The conference home is the Tokai University Educational System. If not for the leadership of Dr. Matsumae and Professor Sakata, the conference clearly would not be making such substantial contributions to the worlds of science and letters. I'd like to thank them.

It has been an honor to have the conference meet in the state of Alaska; it's been an honor for the University of Alaska to participate. I have enjoyed this enormously, since most of the work was done by Professor Shaw and his colleagues. They invited me to simply participate and to learn a lot.

So thank you very much. I look forward to the opportunity of continuing discussions with those of you who are traveling up to Fairbanks.

I also look forward to seeing everyone in British Columbia two years from now. Thank you again. The formal conference is adjourned.

Stewardship and Sustainability of Pacific Fishery Resources: The Need for Critical Insight and an Encyclopedia of Ignorance

Tony J. Pitcher
University of British Columbia
Vancouver, British Columbia, Canada

It is easy to be stunned by more than the sheer enormity of the Pacific Ocean, which occupies 32% of the planet's surface and comprises 46% of its surface waters. The Pacific is the home of tropical island paradises that were the inspiration of Gauguin's art and is the repository of the collective ancient wisdom of native maritime peoples that inhabit its shores and archipelagos from the Aleutians to Samoa and from Taiwan to Chiloe Island. Endowed with a diversity of productive upwelling and mixing zones from polar seas, boundary currents, tropical shelf areas and reefs, the Pacific is also a source of an enormous wealth of natural renewable fish resources. Sadly, we humans have acquired the technology and are innately endowed with enough economic greed that we may squander this wealth through excessive harvesting, environmental degradation, pollution, and mismanagement. This paper provides an overview of Pacific fisheries in hopes of averting the loss of this paradise, by focusing attention on what we do not know.

The unrelenting confidence exuded by much of contemporary science signals that some of us are reluctant to learn that what we do not know is always more important than what we know. For example, recent disasters in the management of fishery resources, compounding a history of similar problems over the past half-century, suggest that this is a misguided view. Moreover, conventional academic science can barely cope with the diverse impacts of our innovative exploitation of natural resources. For example, the introduction of salmon aquaculture to the southern region of Chile has been a great economic success. However, it has also had environmental impact on the aquatic oxygen regime in the Chilean fjords, ecosystem impact through the harvest of sardines and other fish to provide fishmeal incorporated in the salmon feed, and social impact in diverting young people's aspirations from the traditional rural communities where the salmon farms are located. We need broad and interdisciplinary studies to reduce our ignorance of the likely effects of such activities. Furthermore, through a pernicious mixture of expediency, the tendency of institutions to perpetuate themselves, and the hoops that individuals have to jump through to advance their careers, conventional scientific endeavor often concentrates funding on detailed areas that rarely encompass the areas most critical to understanding. When resources are affected adversely, such studies are invariably too narrow, too little, and too late.

The aim of this paper is to set out the limits of our insight of Pacific fishery resources—to present a brief encyclopedia of ignorance as it were—and to identify where we need new knowledge critical to stewardship and sustainability. The paper is divided into three parts: first, a review of the status of Pacific fisheries and their management; second, an evaluation of our knowledge about the major uncertainties and volatilities in these fisheries including the impacts of fish behavior, environmental change, economics, ecosystem, and socio-economic issues in the development of Pacific fisheries; and third, a discussion of the fundamental paradigms used in fishery management policies and assessment techniques. This paper is likely to annoy some of my colleagues among the community of fishery scientists, who will be tempted to label it both arrogant and ignorant in my dismissal of their best efforts. I hope that even if my perspective is disparaged, they will listen sufficiently well to seek their own criticisms of the current state of fishery resource stewardship.

PACIFIC FISHERIES AND THEIR MANAGEMENT

Size, Scope, and Productivity of Pacific Fisheries

The recorded global fish harvest is around 96 million metric tons, but unreported discards and bycatch would increase the true annual catch by at least 30 million metric tons. This amount is approaching the estimated ecological limit for conventional aquatic species of around 150–200 million metric tons worldwide and so there is evidently little scope for expansion of world fisheries. As the human population inexorably doubles to at least 15 billion in the next century, the harvest pressures and allocation conflicts centered on fishery resources will surely increase.

More than 50 million metric tons are caught annually in the Pacific (Figure 1) and this proportion has been increasing over the past ten years (Figure 2). The Pacific produces an average fish harvest of around 0.3 metric tons/km^2, 15% greater than the world average. The reason for this seems to be a richer-than-average endowment of highly productive ocean habitats such as upwelling eastern boundary currents, subarctic convergences, and arctic gyres. Identified globally, 24 large marine ecosystems out of 49 are located in the Pacific region.

Unlike the North and South Atlantic, and with the exception of China, the Pacific tends not to have large areas of continental shelf enriched by river discharges of nutrients from the land. This factor could mean a lower impact on Pacific fish resources by industrial pollution. Given the recent history of new problems caused by contamination from industrial, agricultural, and pesticide chemicals—and the proximity of much of the North Atlantic fish resources to areas heavily contaminated by such products—demand for relatively uncontaminated Pacific fishes may be a feature of future world fish markets.

Major Fishing Nations and Changes in the Pacific Catch

Eleven of the top 14 fishing nations are located in the Pacific (Figure 3) and take the majority of their catch there. In the recent past there have been significant Pacific catches from Eastern European countries such as Bulgaria and Poland; but with increasing domestication of catch within exclusive economic zones (EEZs), the trend is now against distant water fleets, with the notable exception of Japan. Figure 4 illustrates the proportion of the fish catch taken from the Pacific for seven representative nations. The most significant trends are from North American nations with both Pacific and Atlantic coasts, where an increasing proportion of the catch comes from the Pacific as Atlantic stocks have been seriously depleted and

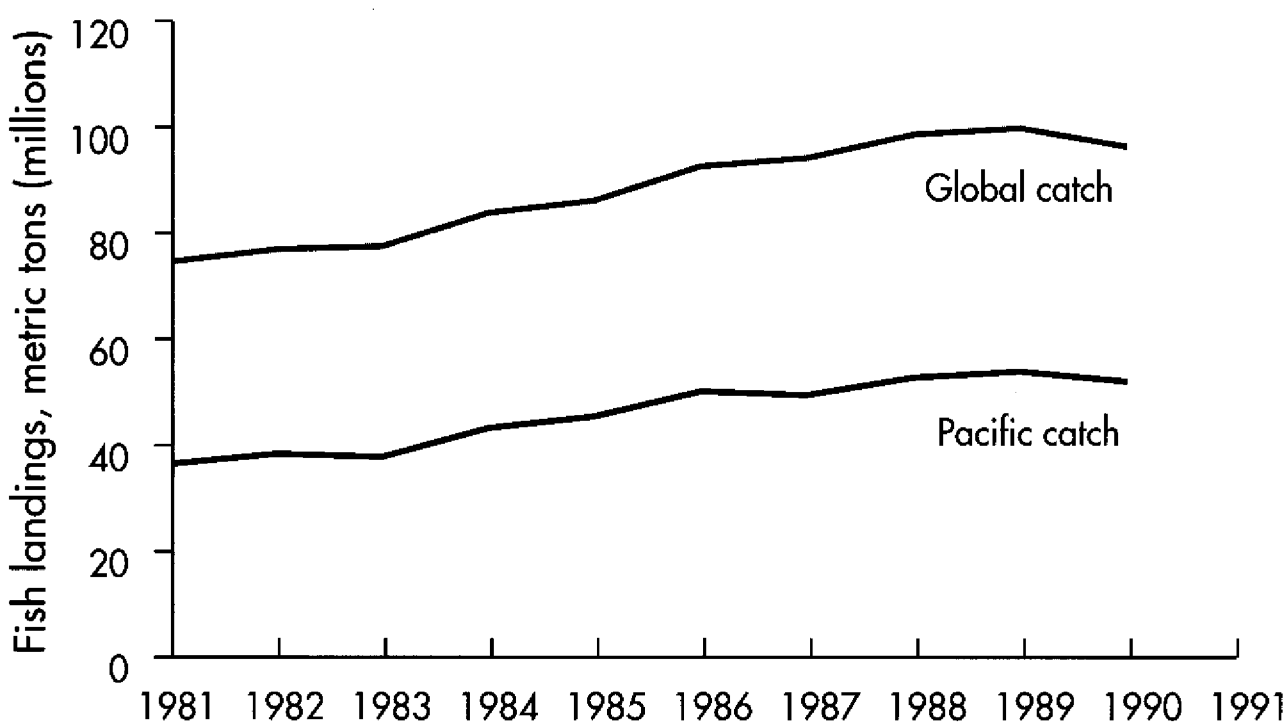


Figure 1. Global and Pacific fish catch since 1981. More than 50 million metric tons are caught annually in the Pacific (from FAO data).

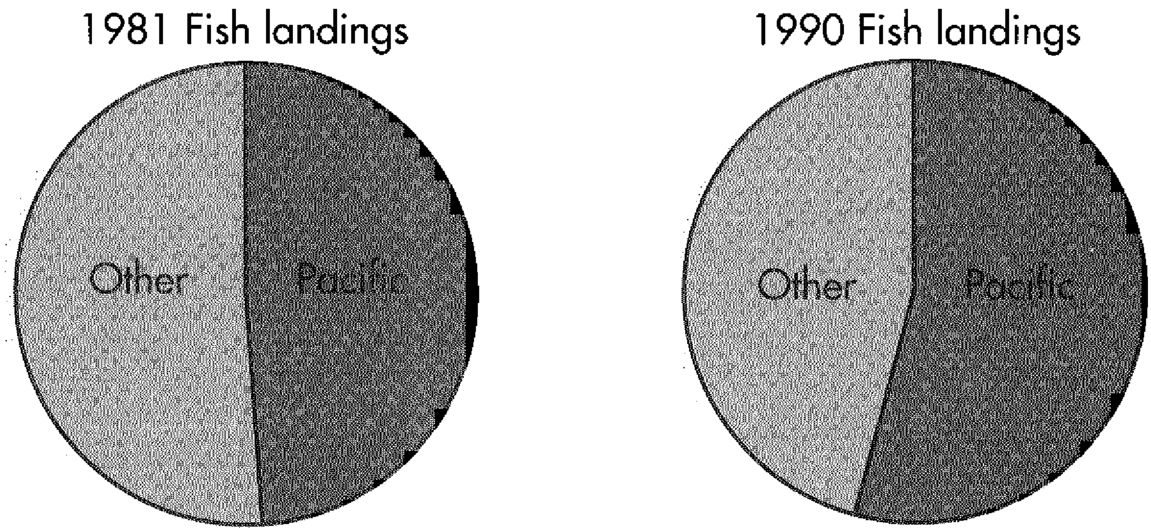


Figure 2. Proportion of world fish catch taken in the Pacific in 1981 and 1990 (from FAO data).

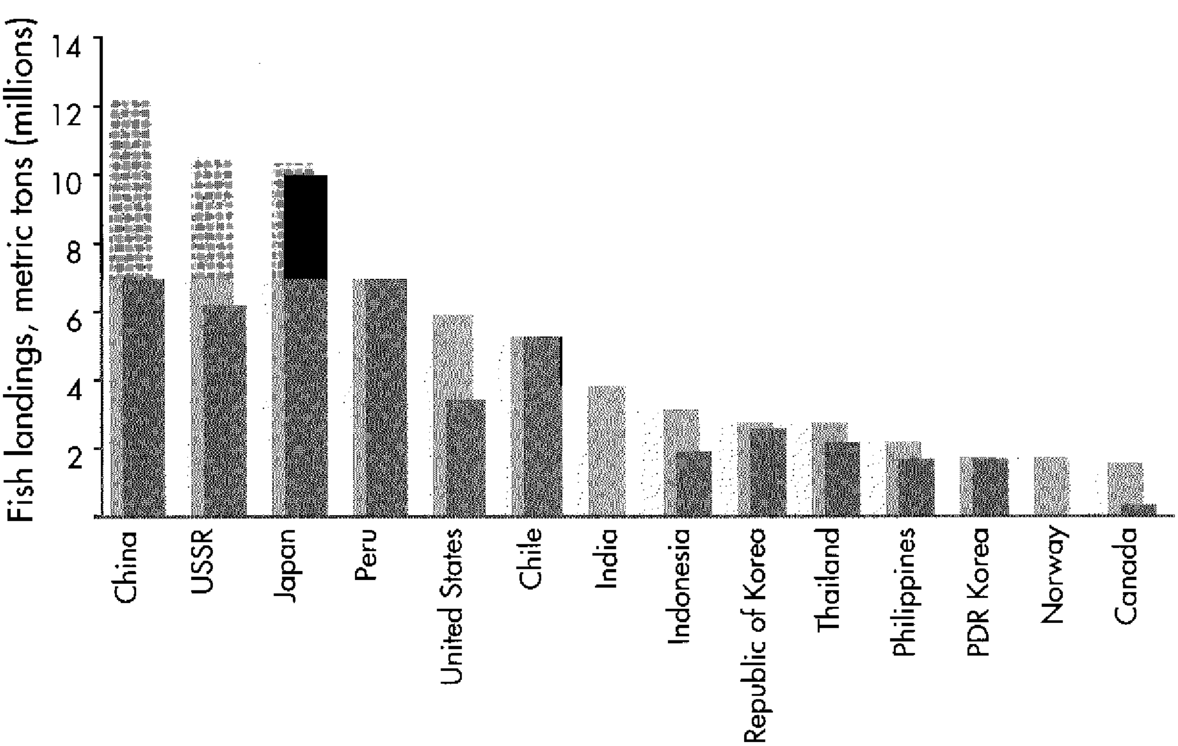


Figure 3. The top 14 fishing nations (1990 data). Eleven are located in the Pacific. Light shading indicates total catch, dark shading is catch taken in the Pacific (from FAO data).

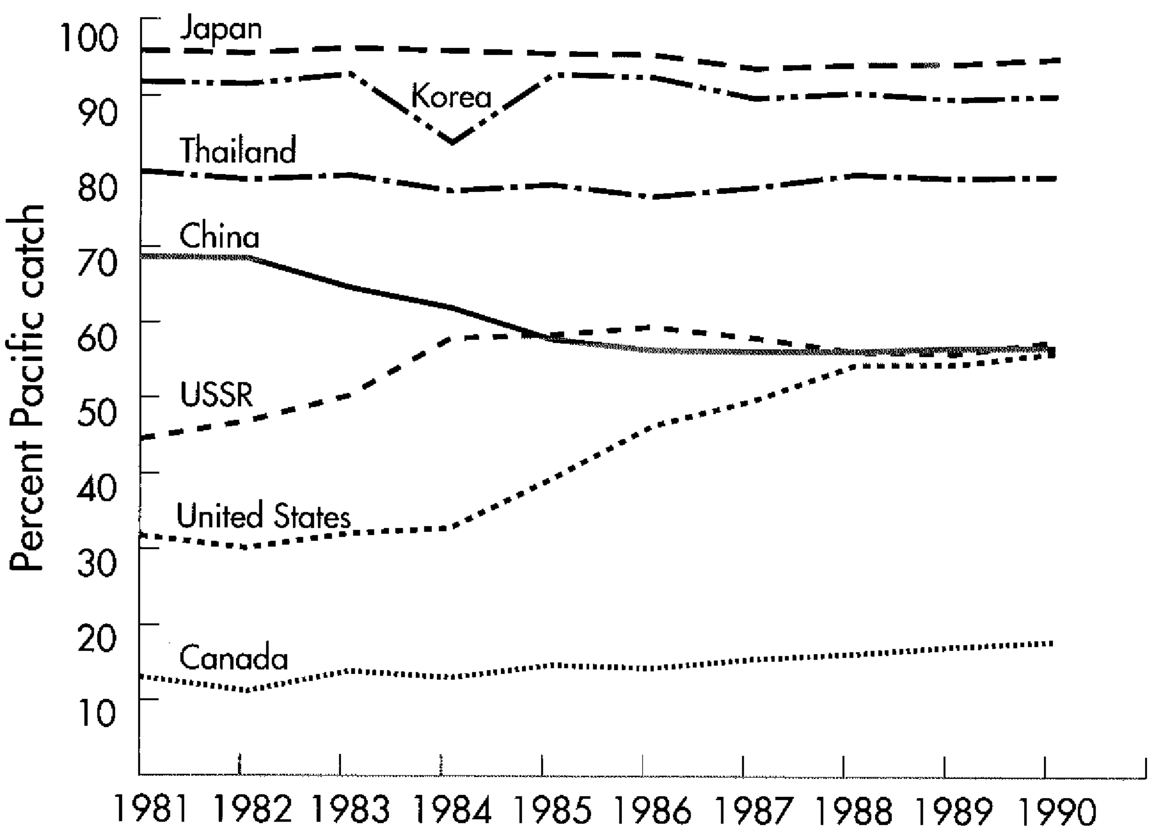


Figure 4. Trends in the proportion of the fish catch in the Pacific for seven representative nations (from FAO data).

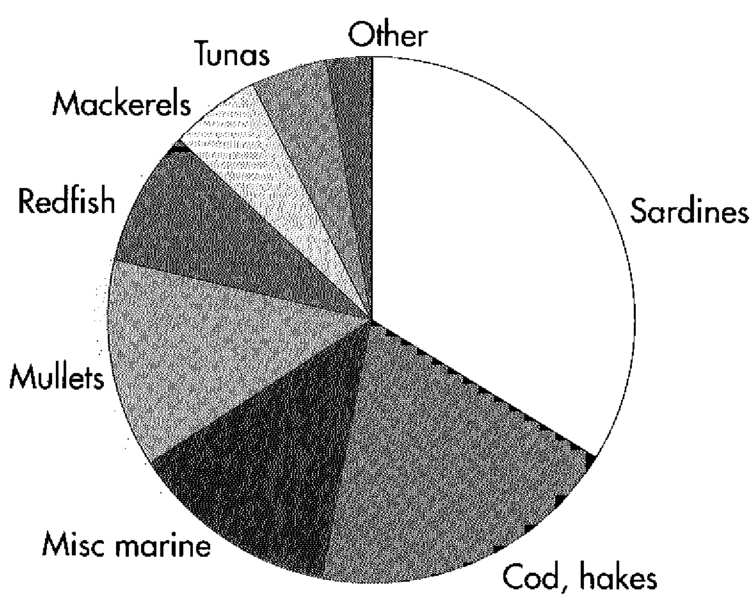


Figure 5. Main fish groups in the Pacific catch (from FAO data).

changes in policy have encouraged domestic fleets. China's large rise in freshwater fish production is reflected in a decrease in Pacific catch, but for most other nations the recent trends are stable. The two major factors evident here are the switch to domestic catch as a consequence of EEZs and the increase in freshwater production though aquaculture.

Major Fish Species and Catch Disposition

The main fish groups in the Pacific catch are shown in Figure 5. Two major fish groups are harvested: demersals (groundfish) like flatfish, cods, and hakes; and pelagic fish like sardines, herrings, and anchovies. Table 1 lists major Pacific fisheries by Food and Agriculture Organization (FAO) statistical region.

The catch goes to four main outlets (Figure 6). Fresh fish including those marketed as altered-atmosphere packed fillets and portions (gas content is modified to inhibit microbial growth); frozen fish products (fillets, blocks); canned and cured products; and industrial fish meal.

The Problem of Poor Catch Data

The problem of inaccurate catch data is a critical area of ignorance in fishery management. Globally, the true annual catch of fish is likely to be 20% to 30% greater than the current recorded amount. Unrecorded, discarded, and illegal catches contribute to a major area of uncertainty not only on account of the dangers of unnoticed current effects on fish stocks, but also because historical catches and catch rates are generally used in assessing fisheries. We have recently seen several nations admit to a history of under-reporting catch data, and there are suspicions that similar problems may be widespread. For example, catch and survey data now available for the first time from Russia and Bulgaria reveal an immense stock of horse mackerel extending across the South Pacific from Chile and Peru to New Zealand. Horse mackerel in the ocean are more dispersed than in the large Chilean purse seine fishery that takes place in the Humboldt upwelling and hence may be caught only with very large midwater trawl gear. At present, such technology bears high fuel costs in relation to market price; but in the longer term, exploitation of this huge fish resource could reach millions of metric tons and become as great as that of Alaskan pollock.

Official catch data may not be much more reliable. The catch figures for the industrial fishery in one country in Latin America were not only 30–40% less than the true catch on average, but fluctuations were uncorrelated with estimates of the true catch back-calculated from fish meal output. In a Southeast Asian country, annual catch data for one region rose linearly and exactly by the percentage

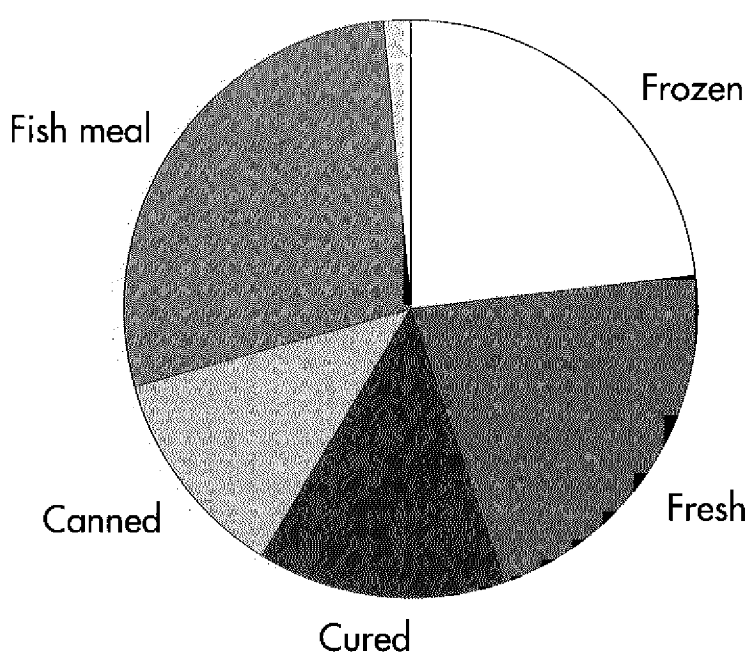


Figure 6. Main outlets for the Pacific fish catch (from FAO data).

Table 1. Principal fishery resources of the Pacific listed by FAO statistical area.

Pelagic	Demersal	Pelagic	Demersal
NE Pacific (67)		**E Central Pacific (77)**	
pollock	salmon	pollock	salmon
hake	herring	hake	herring
sablefish	squid	sablefish	squid
cod	rockfish	cod	rockfish
halibut	perch	halibut	perch
flounder		flounder	
sole		sole	
crabs		crabs	
prawns		prawns	
NW Pacific (61)		**SE Pacific (87)**	
pollock	herring	pollock	herring
cod	sardine	cod	sardine
sole	anchovy	sole	anchovy
flounder	perch	flounder	perch
bream	yellowtail	bream	yellowtail
(multispecies assemblages)	sandlance	(multispecies assemblages)	sandlance
	squid		squid
	shark		shark
	salmon		salmon
W Central Pacific (71)		**SW Pacific (81)**	
groupers	tuna	groupers	tuna
prawns	scad	prawns	scad
snappers	anchovy	snappers	anchovy
bream	horse mackerel	bream	horse mackerel
(multispecies assemblages)	mackerel	(multispecies assemblages)	mackerel

rate per year laid down in the government's 5-year economic development plan; this encouraging linear trend replaced the previous spiky fluctuations in precisely the year a new fishery officer commenced his job. In a developed temperate country, illegal catches of a pelagic fish were estimated to be at least as large as the recorded catch. High-grading of catch during fishing trips has a serious effect on fish stocks in some U.S. coastal trawl fisheries. There are many more examples which cannot be fully documented because of the obvious problems this would cause informants.

Some FAO officials have suggested that the total unrecorded catch could be as much as 30% of the recorded fish catch. In the future, assessment of Pacific fisheries will depend upon the acquisition and sharing of as good an information base as we can get. For example, in some fisheries, catches must be reported by radio as a condition of obtaining a license while an observer program checks on actual catch rates. This is an area where international agreement on catch monitoring and the policing of catch reporting is vital. In the meantime, fishery scientists should not have too much confidence in numerical assessments based on historical catch data.

System Drivers

There are two very different kinds of drivers for the fish harvest system in the Pacific. The first is oceanographic and biological, the second human and economic.

Plankton and Fish Production

Fish are a part of a complex mosaic of biological production systems in the ocean. Although it is a truism that fish production—the integral of individual growth and survival—is higher in more productive ocean regions, many ecologists have found it surprising that phytoplankton biomass and production are not very well linked spatially or temporally to the fish. This is probably because of the different time scale of turnover and because most fish are not herbivores, with the exception of some clupeids that harvest algae directly in upwelling systems. The links with zooplankton are more predictable, as many pelagic fish forage on zooplankton. Benthic fish feed on organisms that depend on the detritivore and decomposer food webs that are only scantily understood.

The theory of trophic cascades has an attractive simplicity and makes some very strong predictions: increased predation on zooplankton should be reflected in increased phytoplankton blooms as grazing is reduced. Alternate trophic levels are predicted to change in opposite directions. Although there is some support from lake ecosystems, there are also some systems where cascade theory does not make good predictions—probably because the primary producer, grazer, and predation sectors of ecosystems are not as homogenous as the theory requires. In general, we are very ignorant of quantitative linkages among all parts of this ecological production system; in fact, some major pelagic energy pathways have only very recently been recognized, such as the microbial loop of tiny autotrophs and grazers that recycle nutrients without much transfer to larger plankton and fish.

To the dismay of the vendors of high-tech science, what can be easily measured by satellite often does not bear much relation to fish yields. Ground truthing is only part of this problem. On a short time scale of days to weeks, sea surface temperatures recorded remotely can predict the location of a species of fish like feeding tuna, spawning Pacific herring, or salmon when they are migrating, but are of no help for important demersal fish like hake or cod. Chlorophyll levels assessed by satellite to estimate primary production have sometimes been very unhelpful. For example, one study in the Californian current estimated higher production in winter than summer. This was probably because the clearer water in winter reflected more total chlorophyll pigment over a greater depth range to the satellite sensor than the denser summer algal crop. Amazingly, satellite-derived primary production levels in the Mediterranean failed to record any influence of the Nile.

Greater practical insight may come from stepping back from the problem by attempting an overview of fish production systems among a diverse range of ocean areas and by asking specific questions about candidate factors using geographic information systems and analogous techniques. Empirical forecasting models employing a range of both physical and biotic ocean indices might be one way. How the critical drivers of plankton and benthos productivity translate to the production of harvested fishes must be clearly understood.

Global Fish Demand

Nowadays there are very few subsistence fisheries. The vast majority of the world's fisheries are prosecuted to make money. The greater part of the fish caught is traded on an increasingly global market that is having a large but ill-understood impact.

Major fish importing nations are in Europe, Japan, and North America; Japan imported over 10 out of 39 billions of dollars worth of fish in 1990 (Figure 7). Changes in the marketing and demand for fish are in the direction of higher quality products. Marketing can stimulate demand for previously unappreciated species. For example, through well-targeted advertising, New Zealand has created a highly profitable world market for unusual deep water species like orange roughy. We are bound to see more such activity as global fish markets become more structured and emphasize value-added products.

The impacts of changes in demand might be evaluated and forecast if we could devise a new type of demand index for fish products. It would need to subsume changes in population, fish consumption per gross national product per capita, types of product, profitability, and acceptability.

In the markets of Western developed countries, social reactions to perceived ecological impacts of harvesting the species might need to be incorporated, as in the demand for dolphin-free tuna that recently impacted the world trade in canned tuna. In practice, a dolphin-free label on a tuna can does not guarantee that dolphins were not killed in its capture for two reasons. Dolphin kill can be greatly reduced, but not completely eliminated, by skillful use of the purse seine. In Mexico, tuna boat skippers, whose decks are monitored by time-lapse video, are given a dolphin kill quota that reduces year by year, and a further bonus to reduce the rate. Also, illegal shipments and transfers of fish are evidently rife in the tuna trade. This example illustrates the complexity and ramifications of an apparently simple economic issue. We are ignorant of analogous effects in other Pacific fisheries.

In Chinese markets, demand for fish species used in traditional medicine—for example sea horses—can have adverse impacts on fragile ecosystems like coral reefs and mangroves. Ways of lessening the effects of such trade while preserving traditional culture, perhaps through aquaculture and licensing, need to be explored.

Economic driving factors have until recently been virtually ignored by fishery biologists, but have evidently been a principal agent in the overharvesting and collapse of many fisheries. We can draw up a substantial historical catalogue of fish stock collapses where both economic and biological factors have placed the harvest system in a realm of fragility. It is a reflection of the lack of communication between fishery economists and fishery biologists that fishery management has appeared unable to learn from its mistakes, and the critical bioeconomic factors that engender collapse have

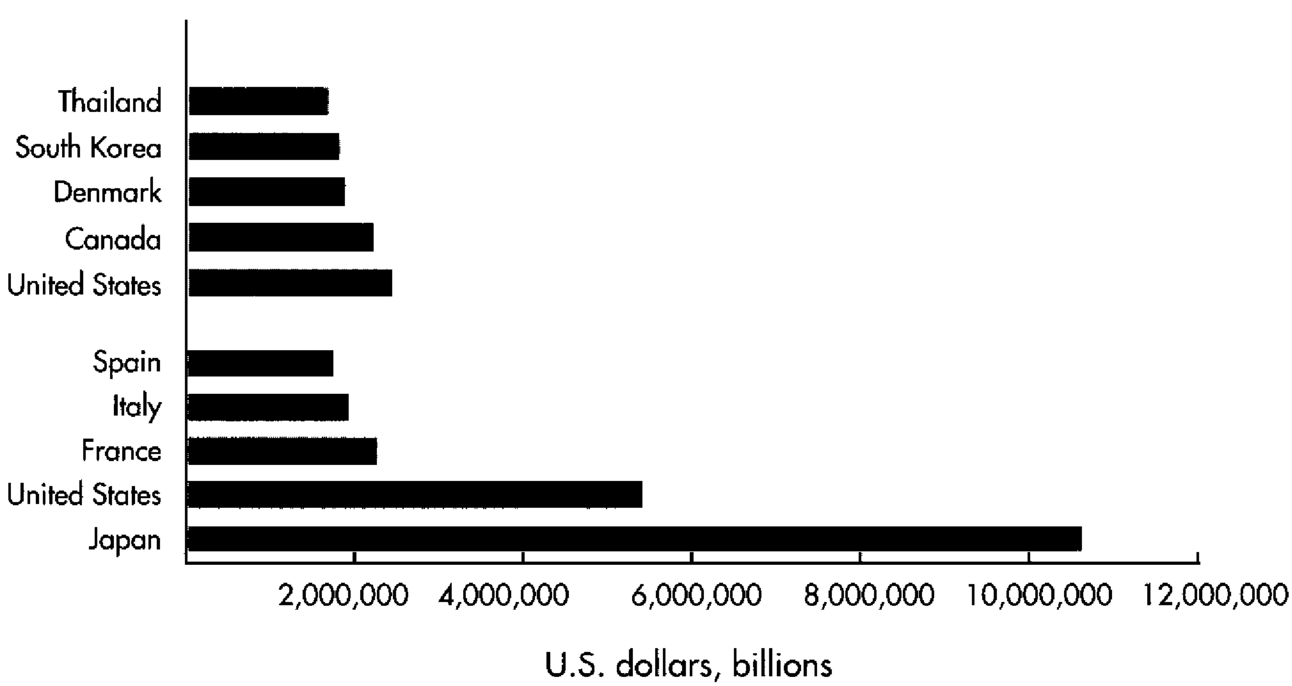


Figure 7. Major exporting (above) and importing (below) fishing nations in 1990 (from FAO data).

not been recognized by either body of experts. Economists can have as much confidence in the power of market forces to preserve fish stocks as the belief of fish biologists in the validity of a yield-per-recruit analysis. The clear history of fishery collapses reminds us that both of these perspectives are flawed. We desperately need insight powerful enough to be able to forecast the impacts of new and unforeseen influences. On its own, the discipline of economics has been as unsuccessful at this as ecology.

SOURCES OF VOLATILITY AND UNCERTAINTY IN PACIFIC FISHERIES

Using current methodology, the biological, economic, and socio-economic drivers described above engender fluctuations and lead to uncertainty in assessment and forecasts for Pacific fisheries. Since we need to be able to understand the dynamics of these systems sufficiently to be able to forecast, the assumption is that higher volatility means a less predictable and more fragile resource. Despite what is often stated about the rigorous scientific method of hypothesis testing, the prevalent paradigm that we see in applied science is actually one of post hoc empirical explanation. Unfortunately, this is especially unhelpful in dealing with volatile and uncertain systems.

Sources of Biological Volatility and Uncertainty

The three principal factors leading to volatility in the biological drivers of Pacific fisheries are habitat, recruitment, and ecosystem processes.

Habitat and the Impact of Environmental Change

The dynamics of the physical template of habitat, like temperature and oxygen, continuously affect fish. Fish species have evolved a range of physiological tolerance, and can cope with larger changes by behavioral means. Very large changes may cause death; the catastrophic outcome of larger changes can alter the nature of fish communities. We have developed some understanding of how small changes in the physical environment alter fish growth, mortality, and migration pattern. General elements of these small and large changes can be investigated by experiment. It is nevertheless disappointing that fisheries ecology has not progressed much further than measuring these population parameters. When large deviations occur in the habitat, fish generally move elsewhere, and our forecasting power in these circumstances is generally no better than guesswork.

For example, high volatility in the abundance of the Japanese sardine is reflected in fluctuations of catch between one and five million metric tons that occur in parallel with changes in the Kurashio current system, but we have almost no understanding of the underlying mechanism. Furthermore, on a time scale of decades, alternations between sardine and anchovy as small pelagic members of upwelling ocean systems have been noted in the Canary, Benguela, Humboldt, and Californian currents. In the latter, fish scales preserved in sediments have shown that such cyclic changes go back 2,000 years. Moreover, fishery biologists have recently been amazed to hear that many small clupeid stocks exhibit fluctuations in parallel on a global scale; that an unknown global geophysical process underlies abundances of small pelagic fish worldwide was totally unexpected.

Distinguishing between the impacts on fish habitats of periodic, cyclic, or fluctuating environmental change and consistent directional environmental change may be useful in focusing on our critical areas of ignorance.

Fluctuating environmental change is always with us and all species have evolved to cope with it to some degree. Larger changes engender volatile or cyclic changes in fish abundance that track measurable environmental parameters like temperature. But the fish communities are essentially composed of similar sets of species over long periods, albeit perhaps with periodic species substitutions (as in the clupeids discussed above). The roles and relative extent of primary producers, plankton consumers, predators, and detritivores are likely to stay about the same.

Directional change, on the other hand, is likely to have quite different results. We might expect to see different fish communities emerge as individual species, their ecological competitors, and predators reach their physiological limits at different points. At some stage in a progressive shift in an environmental parameter like oxygen or temperature, communities might be expected to shift their fundamental character in an episodic, salutary fashion.

Although most ecologists would subscribe to these hypotheses, we do not have a very firm grasp or good predictive ability of fluctuating systems—let alone an ability to make predictions about the impact of directional change. Two examples will serve to illustrate this point.

Periodic Change—El Niño. Quite a lot is now known about the ocean instabilities that trigger El Niño events where warm equatorial surface currents displace cold polar upwelling currents. After the catastrophic collapse of the Peruvian anchovy in 1972, it might be thought that the impacts of El Niño events on fisheries, at least in that region, are well understood. But in Peru there is an opposite influence of El Niño upon anchovy and hake fisheries that appears to be connected with a decrease in the anoxic region in deeper water. Evidently, while we are unable to make specific predictions about the effects of El Niño on anchovy, we do not understand how hake respond to the same events.

During El Niño years, there is a northward movement of hake, sardine, and mackerel in the Californian current driven by the warmer water regime. In 1993, not only was a massive increase in hake available to the Canadian fishery not realized until it happened, but there were other unforeseen impacts. For example, mackerel fed on juvenile salmon which were emerging from the west coast rivers to begin the ocean segment of their life history. Without any clue as to how much young salmon were being consumed by what quantity of mackerel, commercial fishing boats were chartered by the government fisheries agency to attempt to reduce mackerel abundance by purse seining. Such ad hoc management measures lay bare the depths of our ecological ignorance.

Homing Pacific salmon are intercepted by the gauntlet fisheries of the Pacific Northwest—these fish are sequentially challenged by a succession of fishers and gears as they migrate upriver, i.e. they "run the gauntlet." Salmon feed and grow in the open Pacific Ocean, but migrate back to their natal rivers to spawn at the termination of their lives. The exact location of landfall before swimming along the coast to their home river system can make a large difference to the economics of the salmon fishery through the relative numbers of fish returning to the coast in Alaskan, Washington

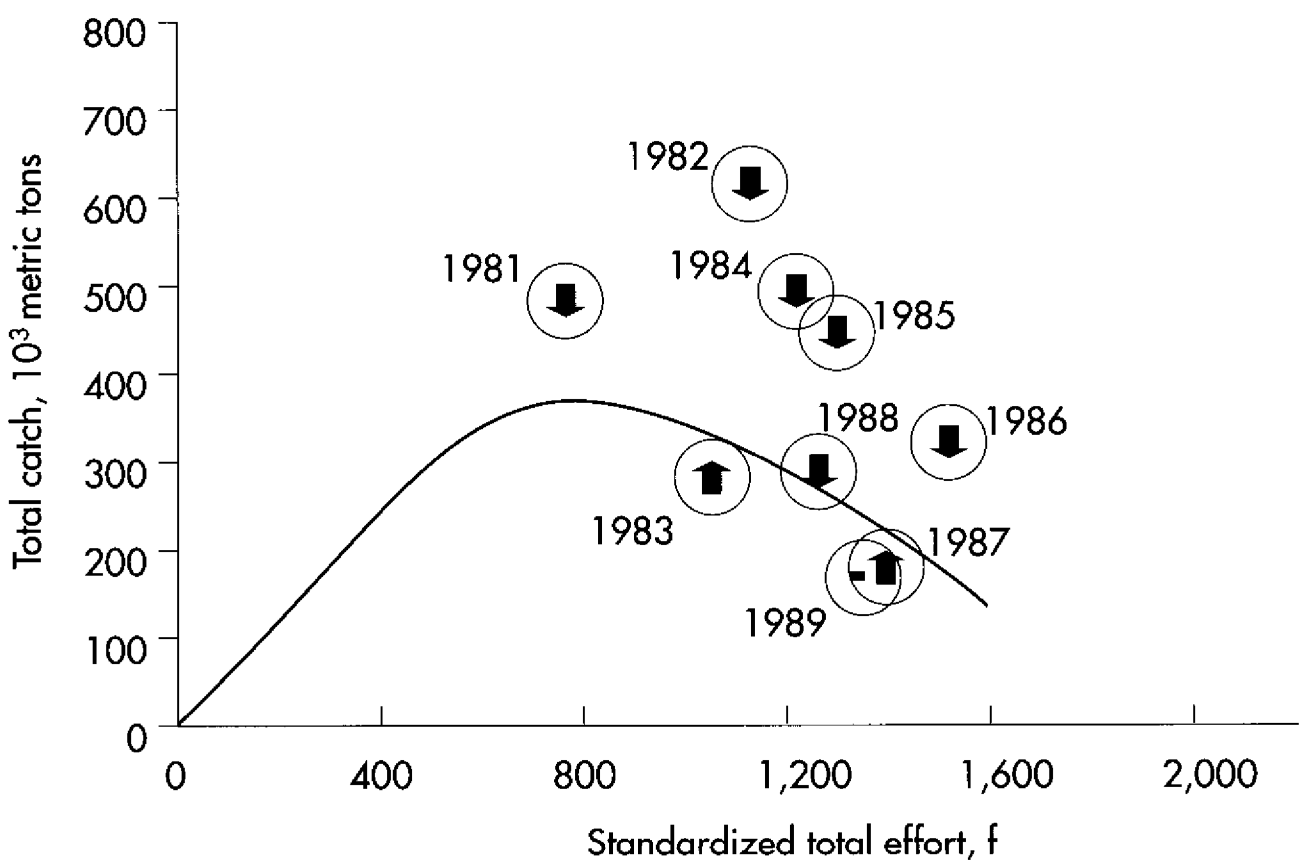


Figure 8. An assessment plot of fishing effort against total catch for Ecuadorean chub mackerel stock made two years prior to the stock collapse (from Patterson et al., 1993).

(U.S.), or Canadian waters. Changes in ocean currents and temperatures from El Niño affect the time and place of return through influence on swimming energetics; but despite 50 years of research, we are still ignorant of the precise mechanisms that salmon use for homeward navigation. Without knowing this piece of physiology, simulation modeling of the migration path in relation to sea surface temperatures, small ocean eddies, and the strength of the Alaskan gyre, can only compare what may happen in a range of scenarios with little power in choosing among them.

Intrinsically, the El Niño instability is of variable strength; the measure of our ignorance is that we do not have a good predictive ability in quantitatively forecasting the consequences.

Directional Changes: Global Warming and Nutrient Enrichment. We are reasonably familiar with the general changes that may occur in fisheries if the global warming scenario occurs as predicted. (It may be worth remembering that we are ignorant of what factors trigger the ice ages and we may equally well be headed for one of those.) These include changes in species composition—as warm water species shift their range northward—and the impacts of higher storm frequency and consequent ocean surface current unpredictability. Notwithstanding several recent conferences on the subject, it is plainly evident that we have almost no predictive power in the area.

Ecological changes accompanying directional climate change will very likely be irreversible by human intervention. When we look at the kinds of changes that will impact humans the most, a litany of ignorance appears. For example, we do not know whether secondary production and ocean biomass will increase or decrease; whether harvestable fish species will be replaced with unsuitable species; whether some ecosystems, such as mangroves and coral reefs, will be eliminated completely. Moreover, on a global scale, we do not know how changes in ocean ecology will affect the major biogeochemical cycles such as that of carbon dioxide.

The directional change produced by nutrient enrichment is thought to have enhanced the productivity of the North Sea and Mediterranean (especially the Adriatic) by some 5 to 15% over the past 50 years. Here a directional environmental change may produce an unequivocal shift in state. In the Black Sea, where the flushing rate is low and nutrient enrichment has occurred, the pelagic system has switched from fish to jellyfish; but the linkage is not understood. In contrast to the situation in freshwater, the downstream effects of human activity are generally poorly documented in the sea.

Recruitment

Recruits are the fish that become vulnerable to harvest. Fisheries scientists attempt to measure their size, age, location, and numbers. The role of new recruits in fisheries varies from some pelagic fisheries like anchovies, where first-year recruits form most of the catch, to long-lived fish like halibut where less than 5% of the catch may be recruits. In the former, recruitment contributes very significantly to volatility in the catch. In the latter, age structure can buffer change for long periods, but in practice, long-term changes in recruitment can ultimately deplete stocks just as much. The major focus of fisheries research on recruitment has been to try to predict the numbers of recruits that derive from a set of spawning adults. The mindset of fisheries ecology has been so patterned by the annually spawning fish of temperate regions that until recently we have virtually ignored tropical fisheries, where spawning and recruitment is often semi-continuous.

In the 1960s, Cushing wrote that recruitment was the last unsolved problem in fisheries ecology. Evidently this is still the case, and in fact it is beginning to dawn on many fishery scientists that the "recruitment problem" may be inherently unsolvable. Not only may the recruitment process itself be intrinsically chaotic, but the detailed ecology from egg through larvae to juvenile and harvested adult is, for most fish species, so extensive—and subsumes so many stages and levels of variation—that man-years of research on even a single species have failed to produce sufficient understanding to build a forecast model. This is true even in anadromous species like salmon where the problem of estimation is greatly simplified because juveniles migrating oceanward and adults migrating upriver can be easily counted. Despite vast amounts of research in the past 30 years, we are not much better off in the case of ocean fish with planktonic larvae. The most useful forecast models of recruitment are empirical regression models that may work, but deliver no actual insight. Even here the levels of uncertainty are high. Every beginning statistics student knows, but professional fisheries ecologists often forget, that regression models have no predictive power outside of the range of the original observation set. For regression models, then, the volatility of the recruitment process in most fisheries means we remain ignorant of the effects of large changes.

One way out of the dilemma of recruitment is to deal head-on with the uncertainty in the recruitment process (an issue discussed in more detail below). But paradoxically, fish that appear to the fishery manager as chaotic and volatile have evolved by persisting in time. An alternative perspective might therefore be to ask questions that reflect this persistence and are more answerable. Perhaps the right questions would embrace the physical and biotic environment in which commercially harvested fish have persisted.

Resilience or Collapse: An Instructive Contrast Between Groundfish and Pelagic Fisheries. There is an instructive contrast between the resilience of groundfish stocks and pelagic stocks that may be used to develop insight of critical problems. Groundfish like pollock, halibut, and hake can withstand heavy fishing; many Pacific hake stocks are overfished by any criterion, while some are so heavily overfished that large numbers of small immature fish are landed and/or discarded at sea.

The fisheries ecology of hake itself is fascinating and immediately presents a number of apparent paradoxes. Hake fisheries, in spite of two major sources of volatility, are quite resilient. Although they may live in a range of habitats, hake are especially characteristic inhabitants of the highly volatile ocean fronts of the productive upwelling regions driven by the world's eastern boundary currents. Yet in the face of both heavy human exploitation and an uncertain environment, hake fisheries show no history of collapse. Also, hake are classified with demersal fish, yet feed voraciously on pelagic and meso-pelagic food through vertical migrations. Designed to rise diurnally in the water column acting as opportunistic ambush predators, hake are intrinsically cannibalistic. In most hake stocks, such cannibalism turns out to be very important.

There are two key factors that underlie the success of hake as a human food resource. First, hake do not group like pelagics and gadoids because of their ambush predator habit and the danger of cannibalism. Hence, as the populations are reduced by fishing, they do not contract into small areas. Catchability therefore remains constant and catch-per-unit-effort (CPUE) declines proportionally. Consequently, hake stocks should be resilient to overfishing and not exhibit the rapid catchability collapses seen in pelagic stocks. Second, cannibalism—which increases with age and length—is an important source of natural mortality in hake and affects the structure and state of the hake populations. It may be a key feature in robustness as it will act in a density-dependent fashion and hence may aid hake populations in recovery from periods of low abundance.

By way of contrast, pelagic fishes like sardines, anchovies, mackerel, and tuna are sociable fish, grouping into fish shoals that have demonstrable advantages for individuals in foraging and the reduction of predator risk. It has recently been realized that there is a hazardous mismatch between behavioral features that have evolved to fit pelagic fishes to a specialized ecological niche and their response to harvesting by humans. The fundamental problem is that the very features that endow these fish with persistence in the pelagic niche make them especially vulnerable to overharvesting to the point of collapse.

Social behavior in the form of shoaling has two consequences for fisheries. First, shoaling may mean that fish are more easily detected by sonar and the like, and hence they may be located and captured almost irrespective of population density. Second, alarmed fish school and pack together, making capture of complete shoals easier by gear such as purse seines or pelagic trawls. The effect of this is that CPUE can remain constant despite decreasing fish abundance and the corollary is that catchability increases as stock size diminishes. This may lead to stock collapse since the mortality rate increases as population abundance decreases. The problem has been termed a catchability-led stock collapse (CALSC).

The critical area of ignorance here is to find measurable population or fishery attributes that might give early warning of CALSC. The problem with all current techniques is that most estimators of catchability are not independent of stock-size estimation. Although some fishery assessment techniques are able to diagnose CALSC, such warnings are still ignored, for example in the recent collapse of the Ecuadorean mackerel stock (Figure 8).

One candidate symptom that may be helpful in signaling incipient stock collapse is the packing of sociable species into restricted areas of their former range; something of the kind appears to have happened in the Newfoundland cod fishery just prior to collapse. Detection and analysis of this symptom depends on retaining precise geographical information with the catch rates of individual vessel—the contrary of the truth-by-averaging approach that was supposed to inspire statistical confidence according to the classical paradigms of fisheries science.

To their horror, fishery ecologists are realizing that with modern fishing gear, the CALSC syndrome may not be restricted to pelagic fisheries. Something similar may have affected Canadian cod fisheries. An important corollary is that CPUE data gathered from commercial fishermen on fish species that are endowed with intrinsic sociability will not provide a reliable signal of population abundance and therefore should not be used in assessment methods that are tuned with CPUE data such as Virtual Population Analysis.

Multispecies Fisheries. Despite years of sustained research, assessment models for multispecies fisheries are still inadequate. Some models are based on empirical correlations, some on top-down effects of predation and consumption rates, and some on bottom-up production of plankton and energy flow. Models based on consumption have proven expensive and nevertheless fail to predict the outcome of quite simple changes. Most multispecies models whose workings are understood are oversimplified. Anything larger than two or three species requires too many parameter estimations, many of which end up being guessed. The relatively simple ECOPATH model is an encouraging new development. This model entails estimation of the energy transfers among ecosystem compartments using assumptions about the ratio of production to biomass, but it cannot predict dynamic changes in systems.

Ecosystem Effects

The effects of fishing at the ecosystem level comprise one of the most important areas of our ignorance. Harvested fish may have other species of fish, squid, or crustaceans as competitors for food, as well as elasmobranch, bird, fish, and mammal predators. The links among species in aquatic ecosystems are poorly understood and fishery ecologists are unable to forecast how harvesting of one species may shift community structure. It is apparent that we have a major critical area of ignorance about how changes in the ecosystem alter fish abundance, location, and community composition. Fish introductions in freshwater, for example, have had unpredictable and ill-understood consequences. All of these factors contribute to volatility. Two issues will be discussed in more detail below.

Bycatch Problems. Globally, the impact and control of bycatch and discards in the marine sector—which have been estimated as at least 30% of the world fish catch—raises a whole spectrum of problems for which we have neither precise insight nor solutions. There are discards of millions of metric tons of small fish worldwide in trawl fisheries for shrimp, high-grading by size in fisheries with minimum size regulations like purse seining for mackerel or trawling for hake. There is also a significant bycatch of depleted species, such as halibut, in fisheries that target other fish. Unreported discards can also have a serious impact on local habitats and ecosystems. It has been estimated that there may be as much as 5 metric tons of discarded fish for every metric ton of shrimp landed in the tropical shrimp fisheries of Southeast Asia and Latin America.

Marine Mammals and Fisheries. The impact of fish predators like sea lions, seals, toothed whales, and humpback whales is poorly understood. Calculations of fish consumption rates are usually based on studies of captive animals that likely bear little relation to how wild sea mammals hunt and feed.

By way of example, in the North Pacific a recent decline in Steller sea lion populations has led to that species being placed on the U.S. threatened species list under the Endangered Species Act. Because of the suspicion that the decline has been caused by poor nutrition in nursing females and pups, fishing within 20 nautical miles of rookeries has been banned. In fact, the changes in population size of the Steller sea lion are complex, and there have been reported increases in some areas on the Aleutians. Consequently, sea lion population dynamics and breeding behavior are being compared in areas of decline with areas of population increase. But we are almost totally ignorant of such key factors as how changes in the sea lion population impact commercially harvested fish and the response of sea lions to low food availability at critical points of the life cycle.

Similar areas of ignorance apply to the ecosystem impacts of whale harvesting and their subsequent population recovery throughout the Pacific Ocean. We have been quite unable to decide whether a huge surfeit of ungrazed krill will appear in the southern ocean, or whether other species have taken over the whale's krill-eating niche. Not only do we not know what might happen, our survey and sampling operations in the Antarctic are so sparse that we do not know what *has* happened.

In tuna fisheries, switching from purse seines to alternative harvest techniques has been considered as a way of mitigating dolphin kills. But this may bring unexpected problems. For example, tuna caught on floating debris are below the optimal harvest size and bring an overhead in the form of bycatch of juveniles of other fish species, and—to the dismay of the conservationists—marine turtles.

Sources of Economic Volatility and Uncertainty

Can we foresee any factors that may be critical to assessing the impact of changes in demand for fish and in the economics of fishing industries among Pacific nations? We seem to have little capacity to forecast such changes, but underlying each of these changes are clear global trends in human fish consumption associated with urbanization, increased structure and sophistication of traditional fish markets, and the demands of aquaculture. In this section I examine sources of volatility in market demand for fresh fish, fish products, fish meal, and recreational fishing.

Fresh Fish Demand

Fish is increasingly flash frozen immediately after capture at sea and thawed on fishmongers slabs, or sold in a frozen state for further storage by the consumer. These trends will surely not reverse. The altered atmosphere pack has revolutionized fresh fish marketing by inhibiting the growth of harmful bacteria prior to sale and is especially valuable in marketing the products of aquaculture. So at first sight, the major trends appear reasonably predictable, but in fact, some circumstances cause demand to be extremely volatile.

Compared to meat, fresh fish has both healthy and unhealthy aspects to its consumer image. The well-balanced amino acids in fish protein, coupled with unsaturated fats and complex fatty acids, raise the nutritional profile of fish as part of a healthy human diet. But counteracting this positive image is experience of food poisoning from bacteria that grow readily in stale fish, and the association with ammoniac and methylamine tastes and odors. An example is the overnight collapse of the fresh fish market in northern Europe following publicity given to human infestation with *Anisarcis*, a cestode parasite. This worm leaves the gut and migrates into flesh after death of the fish, and can even survive chilling and light smoking. Human infestation results in debilitation rather than death. The demand for all fresh fish species was affected even though the parasite is found only in clupeids. Clearly, market demand for fish can be extremely volatile if health issues are raised.

Market demand for fresh fish can also virtually disappear if the fish is not available for prolonged periods. For example, in the 1970s, strong economic demand for herring in Europe raised prices to record level. Stocks were depleted, many stocks collapsed, and a complete ban on herring fishing followed. By the time the unfished stocks had recovered and herring fisheries were reopened ten years later, there was virtually no market demand for herring. Despite attempts at stimulating demand through advertising, prices have remained low.

Demand for Fish Products

The future is likely to see an increase in the amount of fish subjected to high-quality industrial processing by smoking and marinating, and a decrease in traditional, low-quality processing like canning and drying.

Developing nations have steadily been increasing their export of cooked fish products meeting European and North American health import regulations. At present the total quantity is small, but a trend toward the benefits of adding economic value in the country of capture is evident.

In the past ten years, the market for high-quality surimi has expanded beyond its traditional Japanese base. In Europe, the food industry is finding a market for gourmet-quality pre-cooked fish meals that incorporate surimi. In North America there are few products of equivalent quality, but increasing sophistication of the North American market, probably led by the large urban centers with large ethnic Asian populations, means that such demand is only a matter of time.

The processed fish sector may be less volatile than that for fresh fish. In Europe, the market for smoked processed herring was much more stable and buoyant than the market for fresh fish, perhaps because demand could continue to be satisfied by imported fish while domestic stocks were unharvestable.

Luxury Fish Demand

Demand for luxury fish that may be sold at almost any price can have a severe impact on fishery resources; in economic jargon, these fish have inelastic demand and elastic price. The depletion of Pacific lobster, sea urchin, and abalone stocks provide sad examples. Typically, relatively sessile resources like these are progressively and geographically depleted zone by zone. Large migratory bluefin tuna stocks have also been depleted worldwide due to demand by the Japanese sushi and sashimi market. Fresh luxury fish may be flown rapidly by air to the markets in Europe or Japan. The trade is driven by immediacy of large financial reward.

In the tropical Pacific, the drive toward high quality fish commanding premium prices is having some bizarre effects on fisheries techniques. Large tuna caught individually by pole-and-line are landed onto mattresses, then transported in bubble wrap. Fish may be killed by spiking through the brain, or bled to death by cutting a gill arch. Sharks may have their fins amputated for the shark fin soup market, and returned to the water alive, where they die a slow death. Parrot fish caught from coral reefs are removed from their grazing territories, which can severely affect reef ecology.

The luxury fish market probably does not increase economic volatility, but it has a destabilizing impact on ecology. The popularity of luxury fish, including sushi, is slowly spreading through North American and Europe, and one can expect the impact of these demands to increase.

Fish Meal Demand

Over 25% of the world fish catch, especially of small pelagic species, is reduced into fish meal. The trend toward increasing the proportion of fish for direct human consumption is likely to continue because of the higher economic rewards, but the fish meal sector will continue to have a major impact on Pacific fish stocks for a long time to come.

Demand for fish meal for incorporation into feed for aquaculture is volatile. Countries starting fish farming may seek domestic sources to reduce import costs. World prices of fish species that are both farmed and caught in the wild, like salmon, may fluctuate greatly depending on the relative supply of wild and farmed fish. Uncertain catches from depleted wild fish stocks exacerbate this volatility. From the farming sector, supply can easily overshoot demand for new products and species. Moreover, frequent technical advances can bring down fish farming costs in a stepwise fashion. As fish markets operate on a world scale, in common with other commodity markets, these fluctuations are increasingly difficult to predict.

Demand for fish meal for agriculture—a much larger sector—is probably more stable, but the collapse of pelagic fish stocks generally used for reduction to meal may engender volatility in these markets, as well. The 1972 collapse of the Peruvian anchovy and the consequent rise in meal prices for western agriculture provided a classic example of a chain of economic reactions that even helped to bring down governments.

In the developed countries, the processing of fresh fish heads and frames into meal after filleting is a trend that will surely continue as fish processing moves up the size scale. High technology fish meal plants with high protein recovery rates and low odor emissions are becoming more environmentally acceptable.

Recreational Fisheries Demand

In some areas, sport fisheries have a significant impact on the volatility of fish resources, especially where they are already depleted by commercial fishing. This includes large sharks, billfish, yellowfin and bluefin tuna, dolphin fish, salmon, and many reef species such as large groupers. As more species reach the depleted status through commercial fishing, and the demand for recreational fishing increases with the greater structural development of the world tourist industry, volatility from this source will increase. With the exception of North American salmonids and some billfish, our understanding of this area is almost nil.

Economic Volatility

Fish market demand, the economic driver of the Pacific fisheries, can be a significant source of volatility and, as with ecology, areas of ignorance surround many of the critical factors identified here. On a global scale, world fisheries regarded as a single enterprise make a significant economic loss; FAO has estimated that the costs of fishing exceed revenues by 20% ($16 billion: $70 billion revenue, costs $86 billion). The world's fishing fleets have a replacement value of around $330 billion, so the return on capital would have to be to be at least $30 billion to be considered a viable economic activity. Many fisheries are perpetuated by various government subsidies, even if these are not overtly evident. Government subsidies are clearly driven by political expediency and hence must be regarded as sources of high potential volatility.

Impact of First World on Third World Fisheries

First World fleets have intensively fished the coastal waters of developing countries since the 1950s. Originally they had freedom to take large catches while the resource adjacent nations gained little, if any, benefit. The Law of the Sea aimed to change this situation, but First World fleets still fish throughout Third World jurisdictions. They have a reputation for "strip mining" with no regard for the sustainability of the resource, ignoring local fishing fleets, and moving on when catch rates drop. This section examines what we know and critical areas of ignorance about the driving factors and overall impacts of exploitation of such fisheries in the developing world.

The First World catch has decreased in favor of Third World (1W:3W; 55:45% in 1975, 40:60% in 1991). Both developed and developing countries number among the top ten fish-producing nations in the world. These can be divided into three groups: giant producers landing 10–12 million metric tons per annum (China, Russia, and Japan), those in the 5–6 million metric ton range (Peru, U.S., and Chile) and those in the 2–3 million metric ton range (India, Indonesia, Korea, and Thailand). By contrast, in 1980, only Peru, India, and Korea figured in the top ten producing countries.

System Drivers. There appear to be three driving factors in this system: first, demand for fish as a driver of ocean harvesting (discussed above); second, fisheries development improves the economy, earns foreign exchange, creates employment, raises incomes, and generates ancillary employment; finally, although the heydays of distant water fleets are over, the hardware remains and there is continued pressure to fish.

Direct and Indirect Involvement. Direct involvement of First World fishers in Third World fisheries entails paying for access. Payments may be direct or by way of joint ventures and may involve giving aid. Licensing entails fees which may be based on catch royalties, the fishing capacity of the vessel, or lump sum payments. Joint ventures are agreements between two or more partners where each shares the risks, benefits, and decision-making roles. The Third World provides the fishing ground, the First World the technology (fishing boats, gear, trained crew, post-harvesting technology). The First World gets fish, while the Third World, in theory, benefits from First World expertise in order to use the technology in the development of their domestic fishing industry. Joint ventures often involve an aid package. Catches and economic benefits are recorded statistically as belonging to the host nation, but significant profits may be exported back to the developed world.

Indirect investment of the First World in Third World fisheries may include an expected financial return in private ventures or development aid, where ostensibly no direct financial return is expected. Both put money into similar enterprises; for example, into the fish harvesting sector in the form of vessels and technology, into post-harvesting technology, into marketing, and into aquaculture. In the case of development aid, the benefits are intended to accrue to the Third World beneficiary. Development projects are also directed at training of personnel in all sectors, including research and institutional development. The success and suitability of international aid projects has been questioned. Usually some hidden benefit to the First World donor is involved.

Sectoral Conflicts. The expansion of the First World fleet into Third World fisheries impacts existing domestic fisheries, usually small-scale and traditional inshore. Three types of conflict between the two sectors arise; over access, resource share, and markets.

For example, since the 1960s there have been conflicts in Malaysian fisheries among small-scale inshore fishermen, purse seiners, and large domestic trawlers illegally fishing inshore waters. Although 1981 legislation zoned these different types of fishing operations, new conflicts have arisen. In 1985, the Malaysian government acted to develop an efficient modern offshore fishing fleet to increase food catch and foreign exchange. Local entrepreneurs and a joint venture with Thailand invested, both using foreign crew and vessels. The basic success of this operation has been accompanied by further conflict; local applicants were refused licenses and local crew on foreign vessels were harassed. At sea, local inshore fishermen complain that the offshore vessels transgress the 30-mile legal boundary, employ high-powered halogen lights to attract fish, fail to respect other vessel's fish aggregation devices, and disguise themselves as joint-venture vessels empowered to fish in Malaysian waters. The foreign presence exacerbates domestic conflict among the offshore vessels, which can land large catches that depress local fish prices, decreasing the income of the inshore fishermen. Furthermore, small trawlers and the small scale inshore fleet compete for the rich inshore prawn grounds.

The high-tech modern fishing fleet of Chile provides a contrasting example of interaction. Chile has developed its fisheries sector over the last 20 years to become the sixth largest in the world. Investment from foreign investors was encouraged. Successful fisheries exist in the north for pelagic species, in central Chile for oceanic mackerel, and in the south for demersal species. However, even though Chile has developed the capacity to exploit the resources of its own EEZ, its fisheries are still affected by foreign fishing fleets. The purse seine fleet in central Chile, for example, competes with Russian fleets for horse mackerel—a migratory species which straddles the EEZ boundary. In spite of recognized overcapacity in Chilean fisheries and the recognition by Chilean fishery scientists that the horse mackerel fleet appears to be the optimal size, there is a stated desire to increase the catching power and efficiency of Chilean vessels in order to compete effectively with the Russians for the resource. Thus conflict and competition can occur even between large scale fleets operating on opposite sides of an EEZ.

Costs and Benefits to Host. By way of analysis, four categories of costs and benefits to the third world host can be identified: economic, social, biological, and environmental. Potential benefits to the Third World from First World fishers are found in economic and social categories. Finance and aid from licensing and joint venture agreements may provide foreign exchange, new technology, training, development, new fisheries infrastructure, primary and secondary fishery jobs, and increased standards of living. New markets may be opened to Third World fishers and new value-added fish products introduced. All these factors help promote economic growth in the developing world.

On the other hand, there may be substantial economic and social costs. Local fish prices may fall and markets may deteriorate or shift to urban areas. There may be high costs for fishery monitoring, assessment, regulation, and high-tech imports for modern fishing vessels and processing plants. Socially, loss of traditional livelihoods may result in unemployment in the fishery and post-harvest sector, and there may be displacement of peoples, social divisiveness, and cultural disruption. In practice, foreign partners often take more than their anticipated share of profits in joint venture operations by introducing inappropriate technology and inhibiting local development of an appropriate small sustainable scale. For example, the offshore tuna fishery in the South Pacific Islands requires high-tech vessels and gear which few of the island states can afford. Similarly, offshore squid fisheries are only profitable when high-tech jigger vessels are used.

Biological costs of First World fishers in the Third World include stock depletion and worse. Ecuador, for example, partly shares its chub mackerel stock with Peru. In Peruvian offshore waters, a substantial Eastern block fleet has been fishing for mackerel for the last 20 years, imposing a high fishing mortality. This illegal catch, unacknowledged by the Peruvians and Ecuadoreans, could well have been a factor in the recent stock collapse of chub mackerel.

The example of the South Pacific Island States tuna fishery is not so gloomy. The Law of the Sea gave the 22 island states of the South Pacific control over the world's largest tuna fishery. Landing skipjack, yellowfin, big eye, and albacore, it contributes almost 60% of the total global tuna catch worth over US $2 billion per year. There are small local pole-and-line fleets, but the fishery is mainly carried out by licensed foreign vessels from Japan, United States, Korea, and Taiwan using longline, purse seines, and pole-and-line. Through a set of "harmonized minimum terms and conditions" laid down by the South Pacific Fisheries Forum Agency, revenue is generated with minimal negative impact on the local economy. Management appears reasonably effective in limiting fishing effort and as a condition of licensing, vessels report catch, effort, and position in detail.

What Can Be Done?: A Conceptual Model of a Complex Multidisciplinary System. A conceptual descriptive model (Figure 9) of this system begins with the three system drivers and follows through the harvest, processing, employment, and general economic sectors. A key feature of this model is that factors have a feedback influence on decisions regarding access by the fishers and resource owners.

This multidisciplinary system has provided valuable insight into a major set of fishery conflicts. But the knowledge about what to do about this complex interlinked system of biology, economics, social policy, and community activities is the missing critical element.

The regional cooperation in the South Pacific Island States tuna fishery may point one way forward, but we are still ignorant about why this particular scheme works where many others have failed.

CRITICAL ISSUES IN FISHERIES MANAGEMENT

Policies that Control Access

One truism about fisheries management is that only rarely are the goals of management at all clear or explicit. The corollary is that the full impacts of management policies are not very often appreciated or even expected. Four management policies will be briefly examined below: control of access, catch and effort quotas, transferable quotas, and cooperative management.

EEZ Regulation: Access and Allocation

The global establishment of 200-mile EEZs by the U.N.-sponsored Law of the Sea conference has been the single most successful piece of international legislation in recorded human history. On its

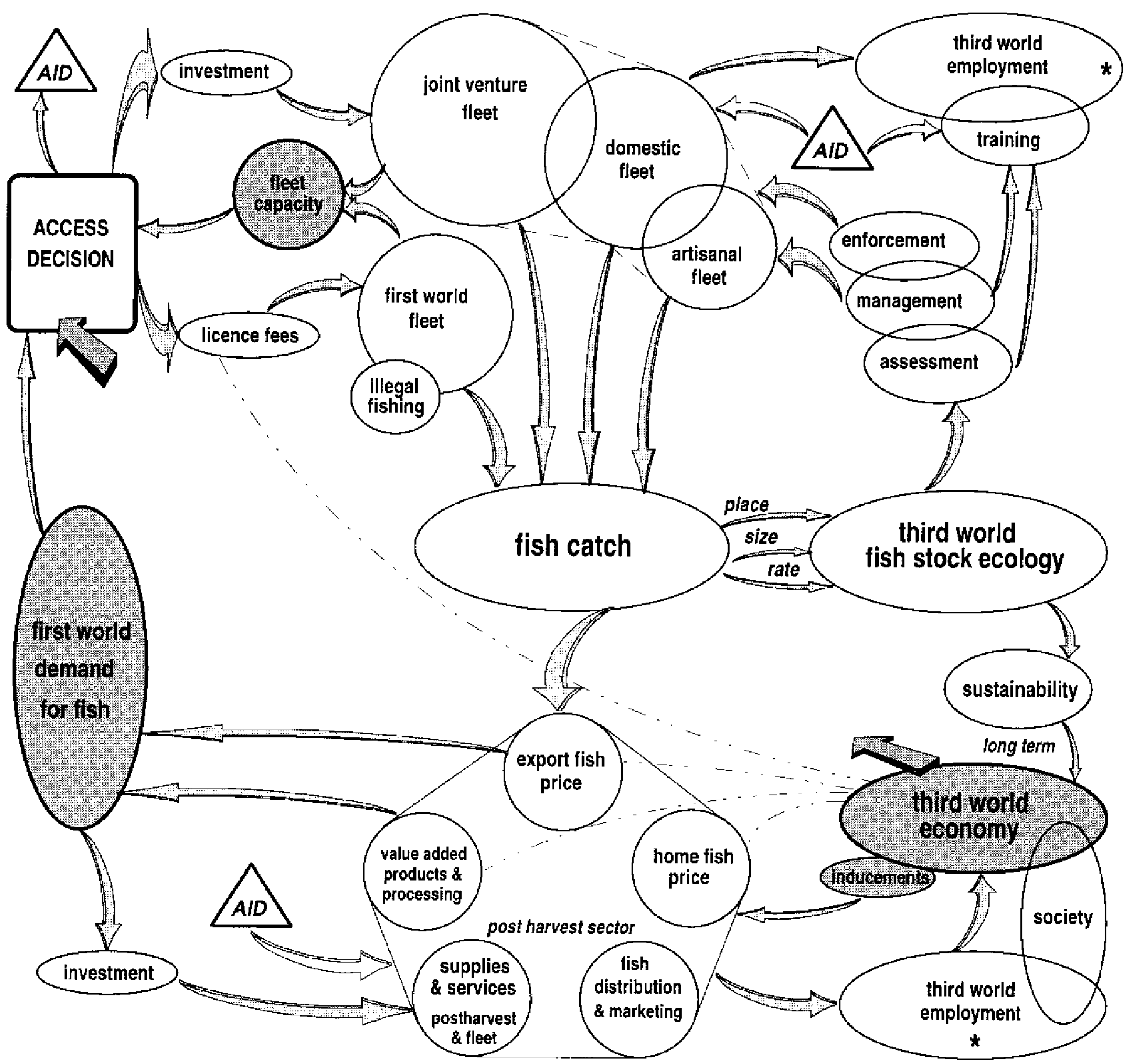


Figure 9. A conceptual model of the impact of First World fishers on Third World fisheries. Arrows indicate influences; broken lines indicate economic benefits to Third World economy. The three system drivers are in shaded ovals. Further details are given in the text (from Bundy and Pitcher, in press).

own it is not enough to counteract resource depletion, but without it, given the power and mobility of modern fishing vessels, the world oceans would be barren of fish today. The development of the fisheries of New Zealand and the success of foreign licensing plans in Pacific Island States would not have been possible without the EEZs. International agreements now follow in the footsteps of the U.N. Law of the Sea auspices. For example, the fishery for Alaskan pollock is one of the biggest fisheries in the world, yielding a combined U.S. and Russian catch on the order of 5 million metric tons per year. A recent agreement to regulate catches in the only remaining international waters of the Bering Sea, known as the "donut hole" (Figure 10), should ease depletion symptoms in the Bering Sea stocks of pollock. Given the catching power of modern fishing vessels and gear, limited and licensed access is essential for all world fisheries.

Limiting access to a fishery has a corollary; it necessitates catch allocation. License fees permitting foreign fishing comprise a significant source of revenue and foreign exchange in the developing world. This may be maximized if allocation of international licenses is by auction. Joint ventures with foreign vessels or capital can help develop domestic fishing capacity both on shore and in the form of fishing vessels. But there are some uninvited consequences of this ostensibly benign system.

Allocation among competing domestic sectors is likely to lead to conflict and is much more difficult. Particulars vary tremendously among locations. In general, it is easier to settle disputes among sectors who have traditionally fished the resource together; more serious conflicts arise when groups emerge who have been excluded or which are not recognized as domestic by existing stakeholders. In the European Community, conflicts between the traditional nations are common even though most fish resources are now held in common. Other emerging free-trade associations in North and South America and in Southeast Asia might try to learn from the unpleasant European experience in this regard.

Moreover, the emerging political consciousness of native peoples, after suppression by colonizing Europeans or Asians, has led them to claim stakeholders rights in fishery resources that have been denied to them. Traditional fishing methods from their cultural inheritance are usually not controversial but are rarely competitive, and native peoples are increasingly demanding access to the fish resource on a equal footing with existing fishing sectors. These trends of conflicts over access and allocation will surely continue.

Catch and Effort Quotas: Enforcement Issues

Catch and effort quotas, usually implemented as TACs (total allowable catch) or VAQs (vessel allocated quotas), have been the mainstay of fisheries management for over 20 years, and their mathematical and ecological basis and effects are well understood. They are useful tools with which to keep back the floodgates; but, as fishery economists have pointed out, there is always a creeping increase of effort because competition among fishers is inevitable.

Individual Transferable Quotas: Stakeholders Rights

The ITQ system has been promoted as a panacea for all fishery ills because stakeholders who buy a portion of the resource are deemed to have a long-term interest in its rational and sustainable exploitation.

This view makes several assumptions that may not be true. First, it assumes that managing stakeholders can acquire perfect information about what is happening to the resource as a consequence of their fishing. The reality is that the best of such estimates are riddled with major uncertainties. Second, it assumes that high interest rates do not tempt fishermen to maximize their income by liquidating the value of the resource now because its long-term value will vanish in a few years. The right to sell a worthless quota in a fishery may not be an attractive option when real estate may be a better inheritance for grandchildren. Third, it assumes that subsidies to fishing are discontinued. In practice, a number of hidden subsidies often stay in place after ITQs are sold. Fourth, it assumes that long-term benefits of a nationally owned resource may be sold to just one group of the population. This may be politically unacceptable and inappropriate for a developing nation with limited resources. A developed domestic fishery sector may be a prerequisite.

A fifth problem is that selling a fish resource in this way can have unforeseen perspectives on a longer time scale. The resource may disappear through purely natural factors such as climate change, so the value of a marketable ITQ would be reduced to zero. Resource collapse may also occur when seemingly reasonable fishing levels act in conjunction with some natural changes in the environment. Fishers are not stupid and it is for this reason that few would be willing to buy ITQs for most clupeid stocks. Moreover, changes in fishing technology that reduce the costs of fishing for larger vessels will ultimately bring about the amalgamation of the original quotas and the fishery will end up with one or a small number of owners, reducing the competitive advantages inherent in the original ITQ system.

A pure market-driven ITQ fishery system has never been implemented as there are always political pressures to exclude access to certain groups, notably foreigners, from the market for quotas. Some "ITQized" fisheries are run by related families in a quasi-tribal arrangement.

Fishery scientists and economists are looking anxiously at fisheries where ITQs have recently been implemented in Canada, the United States, New Zealand, and Iceland. Evidently we are truly ignorant of the outcome.

Cooperative Management

Fisheries anthropologists and others have suggested cooperative management (co-management) as another panacea for all fishery ills. The idea is that stakeholders and managers voluntarily meet to work out and agree on the trade-offs required for management. It is a form of power-sharing and a means of empowering stakeholders, although in

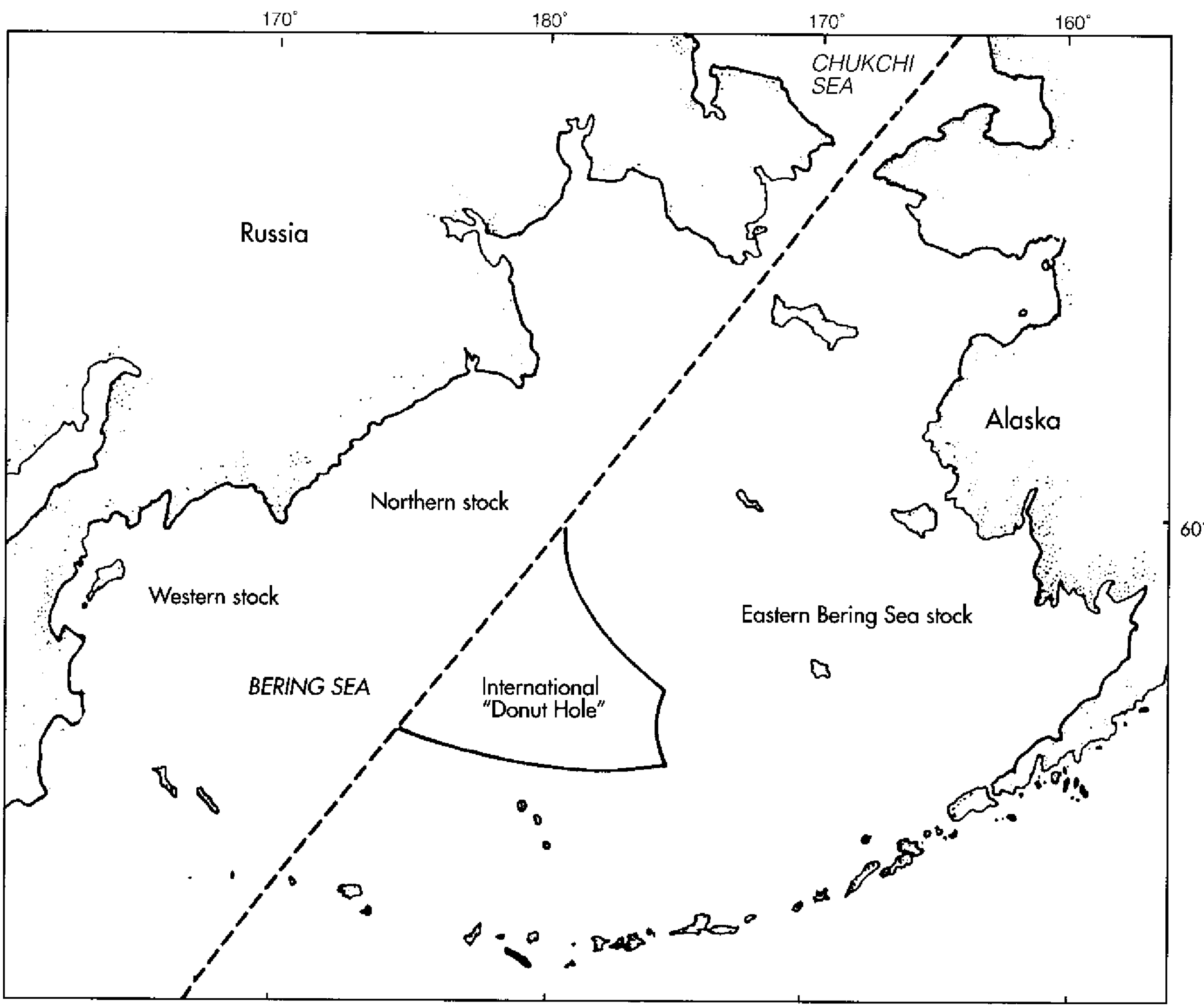


Figure 10. The international "donut hole" in the Bering Sea. 1991 Alaska pollock catches in the donut hole were 0.9 million metric tons, with 1.1 million in the east and 0.7 million metric tons in the West Bering Sea zones.

many cases the governmental interest will retain the ultimate power of veto on collectively agreed issues. In some small-scale Pacific fisheries—for example in the Philippines coastal fisheries—co-management has emerged naturally as local communities have become aware of the economic consequences of sectoral conflict.

Key elements in co-management are: direct involvement at a local level, a willingness to listen to and get to know other stakeholders, a desire for equity, continuity of participation, clear definition of the problem, and an awareness that all should emerge from the decision process with some perceived gain.

Implementing this beneficial system becomes more difficult the larger and more industrialized the fishery resource. In both the developed and developing world, large economic interests, including governments, find it hard to resist steam-rollering any opposition. The process also tends to assume that participants are folk of good intentions and ethical behavior who will not cheat. Unfortunately, most experience suggests the opposite. There is little evidence to suggest that small local communities involved in co-management will be any more effective at policing those who break the rules than large scale authoritarian governments. We have to cope with the fact that a great deal of human economic activity is illegal and corrupt throughout the world and that this will have an impact on our fishery resources.

So our critical ignorance here is of processes that can encourage successful cooperative management. If we were to understand these, fisheries would be better managed.

New Perspectives on Fisheries Management

Factors influencing fisheries management are multidisciplinary, entailing study of the physical attributes of habitats, numerical and physiological ecology, economics, social behavior, anthropology, and political policy. There are critical areas of ignorance for nearly all of the major issues impinging upon the future of Pacific fisheries. This concluding section provides some perspectives on the concepts and methodology used in assessing fisheries.

New Management Units for Fisheries

The recent development of the large marine ecosystem concept (LME) is one innovative way. An LME has boundaries reflecting meaningful ecological discontinuities based on critical ocean features. The hope is that management regimes could be focused on individual LMEs, since LMEs constitute entities more congruent with the systems affecting harvested fish than arbitrary political boundaries in the sea. Of course, a willingness to cooperate across national boundaries is a prerequisite for such management. Some LMEs comprising relatively few political divisions and ecological areas, like the Humboldt current system, would be relatively easy to manage as a whole. Others, like the South China Sea, encompassing many different political jurisdictions, would be more difficult.

Sustainability, Methodology, and Supermodels

Although fishery management goals have long embraced the concept of the sustainability of harvests from the resource, it may be plausibly argued that no fishery ever managed has been successfully sustained. Many have argued for a paradigm shift away from MSY (maximum sustainable yield) toward goals that better reflect whether the underlying biomass of the resource is sufficiently abundant to replace itself in the face of likely environmental fluctuations in carrying capacity. Currently, fisheries ecology is in a state of flux as candidate ideas are put forward and criticized. At present, no single idea dominates the field in the way that MSY did 20 years ago.

The gospel from the MSY era—that catch-per-unit-effort from commercial fishing vessels directly reflects fish abundance—had been under attack for some time, especially in relation to pelagic fisheries. But it has now been severely shaken by the unexpected and complete collapse of the Newfoundland cod stocks. These stocks had been managed by Canadian fishery scientists using the most sophisticated numerical methodology available. The spotlight is now on independent methods of estimating fish abundance such as experimental surveys and acoustic methods. Estimations based on such independent surveys have shown, unfortunately post hoc, that the cod was headed for disaster ten years prior to the ultimate collapse.

Some have hoped that we may be able to employ super-scale models such as those used by meteorologists and oceanographers to forecast physical processes using vast spatial arrays of processes: a recent run of 25 years of a North Atlantic model took 1,000 hours of Cray supercomputer time. But a major difficulty in implementing such biological forecasting models is that we rarely understand the ecology sufficiently well to model it in this way.

A more hopeful approach is to try constructing models that interface physical with biological processes occurring on very different spatial and temporal scales.

Uncertainty and Risk Assessment

One major technical advance in the past ten years has been the development of assessment methods entailing explicit consideration of risks and uncertainties. Modeling generates probability distributions of likely outcomes of management strategies so that uncertainty is taken into account when decisions are made. Unfortunately, this does not reduce the impact of having got things wrong if indeed things do go wrong.

Nevertheless, this set of methods has allowed management advice to become much more sophisticated. Optimal trade-offs among average catch, variability in catch, risk of stock collapse, and employment maximization may be estimated, together with a quantitative evaluation of the major uncertainties involved. Management tactics in the face of uncertainty are to hedge bets, probe and experiment, and try to carry out actions that are reversible. These innovative concepts of adaptive management, although they have been around for more than ten years, have yet to be implemented in practice. This illustrates the inertia inhibiting the relinquishment of traditional methods and concepts when new light is shed on areas of ignorance.

ACKNOWLEDGMENTS

I would like to express my thanks to the organizers of the Fourth International Symposium of the Conference of Asian and Pan-Pacific University Presidents for stimulating the production of this paper, to the many participants at the meeting who discussed these ideas with me, to Alida Bundy for discussion of ideas and for reading parts of the manuscript, and to the editor of this volume for his patience.

FURTHER READING

Bundy, A. and T.J. Pitcher. 1994. First World fishers and Third World fisheries: Impact on resources, economy and society. In press.

Clark, C. 1991. Economic biasses against sustainable development. In: R. Costanza (Ed.), Ecological economics: The science and management of sustainability, pp. 319–330. Columbia University Press, New York.

Crawford, R.J.M. 1987. Food and population variability in five regions supporting large stocks of anchovy, sardine and horse mackerel. In: A.I.L. Payne, J.A. Gulland, and K.H. Brink (Eds.), The Benguela and comparable frontal systems. S. Afr. J. Mar. Sci. 5:735–757.

Csirke, J. 1988. Small shoaling pelagic fish stocks. In: J.A. Gulland (Ed.), Fish population dynamics: 2nd edition, pp. 271–303. John Wiley, New York.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: Choice, dynamics and uncertainty. Chapman and Hall, New York.

Kitchell, F.K. 1993. Food web management: A case study of Lake Mendota. Springer-Verlag.

Ludwig, D.R., R. Hilborn, and C.J. Walters. 1993. Uncertainty, resource exploitation and conservation: Lessons from history. Science 260:17.

Mann, K.H. 1993. Physical oceanogaphy, food chains and fish stocks: A review. ICES J. Mar. Sci. 50:105–119.

Patterson, K.R., T.J. Pitcher, and T.K. Stokes. 1993. A stock collapse in a fluctuating environment: The chub mackerel *Scomber japonicus* (Houttuyn) in the eastern central Pacific. Fisheries Research 18:199–218.

Pitcher, T.J. and P.J.B. Hart. 1982. Fisheries ecology. Chapman and Hall, London.

Pitcher, T.J. and J. Alheit. 1994. What makes a hake? A review of the critical biological features that sustain global hake fisheries. In: T.J. Pitcher and J. Alheit (Eds.), Hake fisheries: Biology, management and markets. Chapman and Hall, London.

Pitcher, T.J. and J. Parrish. 1993. The functions of shoaling behavior. In: T.J. Pitcher (Ed.), The behavior of teleost fishes: 2nd Edition, pp. 363–439. Chapman and Hall, London.

Pitcher, T.J. 1994. The impact of pelagic fish behavior on fisheries. Scienta Marina. In press.

Sherman, K., L.M. Alexander, and B.D. Gold (Eds.). 1993. Large marine ecosystems: Stress, mitigation and sustainability. American Association for the Advancement of Science, Washington, DC.

Sissenwine, M.P. and A.A. Rosenberg. 1993. Marine fisheries at a critical juncture. Fisheries 18:(10)6–14.

Smith, C. and P. Reay. 1991. Cannibalism in teleost fish. Rev. Fish Biol. Fish. 1:41–64.

Tyler, J.A. and K.A. Rose. 1994. Individual variability and spatial heterogeneity in fish population models. Rev. Fish Biol. Fish.4:(1)99–123.

Wilson, J.A., J. French, P. Kleban, S.R. McKay, and R. Townsend. 1991. Chaotic dynamics in a multiple species fishery: A model of community predation. Ecol. Model. 58:303–322.

DISCUSSION

*(**Carol Reinisch**, Tufts Veterinary School.)*

There's a big push in the United States now toward biotechnology, transgenic pigs, transgenic chickens, etc. What impact will that have on the fisheries? If you could take out the entire fish meal component, would that provide a lot of relief? Would that relieve it by 20%? 40%?

Pitcher. That's an area of our ignorance. I wouldn't know how to come up with that proportion. But it would help. It could only be beneficial to reduce the demand for fish meal and agricultural feedstuffs in the developed world. In many areas of the world where most of the fishing sector is concerned with producing fish meal, the waters are short in protein. It is heartbreaking to see the most beautiful mackerel and other fish landed and turned straight into fish meal when it ought to go for direct human consumption. On a global scale, movement toward that process would be a good thing. That's not to deny that there is not going to be demand for fish meal; but some fish meal producers around the world take the heads, bones, and guts of the fish after taking the fillets out for human consumption. You can produce quite high quality fish meal from the discarded material. So what we want in the long run is both of those industries, fresh fish and fish meal, to go in parallel.

*(**Georgy Elyakov**, Russian Academy of Sciences.)*

In many countries, for instance Japan, Russia, and the United States, there are aquaculture plants. What impact does this activity have on the overall fisheries situation?

Pitcher. According to data presented by Ray Hilborn, who works in Seattle, and Carl Walters at the fisheries center of the University of British Columbia, the huge Canadian salmon enhancement program has been very good for creating employment and very good for creating awareness of the natural environment among everybody from scientists to school children, but it's done very little to enhance the number of salmon in the sea. We have to look dispassionately and very, very carefully at aquaculture projects that aim to enhance the natural productivity of the ocean, because one of the largest in the world appears not to have worked.

*(**John Kelley**, University of Alaska Fairbanks.)*

Perhaps I missed it in your conceptual model, but it seems that another major factor is the future demographics of the world. We now have about five billion people living on the face of the earth and presumably customers for these fish. By the year 2050 it seems, if I'm not incorrect, we may be looking at 10 or 11 billion people having quite a taste for these fish, both Pacific or Atlantic. Would you care to comment on what you may predict as to the pressure for these fisheries, which probably aren't growing as fast as the number of human consumers?

Pitcher. With 15 or 20 billion people on the planet by the end of the next century, the pressure on all food resources and the need for economic activity is going to be tremendous. I did point out that with the stocks that we know about we're not going to get that much more fish out of the Pacific. The different processing factors, the reduction of fish meal, the return to direct human consumption is going to be important. The allocation of those resources to the nations around the Pacific will be even more important. We have agreements about particular sets of species in particular parts of the Pacific, but the fish market these days is global.

Eighteen months ago, I was in Bremerhaven, Germany at a conference on hake. Peruvian representatives were at this conference. A representative for a Seattle company of four catcher boats was also present. The Peruvian stood up and showed his diagram of the hake stock off Peru, pointing to one in the north of Peru which he said was underexploited. Our friend from Seattle left the room, got on the telephone, and you could see these four catcher boats changing direction, steaming down across the equator. That's just an anecdote, but the pressure on those Pacific resources is going to be tremendous. The allocation of those resources among the competing nations and markets is even more important than biological considerations.

Establishing Rapport Between Indigenous Coastal Cultures and the Western Scientific Community

Larry Merculieff
City Manager, City of St. Paul
St. Paul Island, Alaska, U.S.A.

I am an Aleut, a people of the Bering Sea for almost 10,000 years, numbering some 3,000 in the world. It's difficult to tell you what an Aleut is. It's easier to tell you what we are not. We are not Eskimo; but we are related. We not American Indian; but we are related. We're not Japanese, Korean, or Chinese, but our roots do come from Asia. When in Japan we are easily mistaken for Japanese; when in Mexico we are mistaken for Mexicans. We are comfortable among all these people, so I guess if there is such a thing as a pan-ethnic group, that's the Aleuts.

Aleuts consider it undignified to single oneself out as the focus of a group's attention, as I am doing here in this presentation. It's also considered undignified to talk so much, as I'm about to do for 45 minutes. In Aleut culture, we are expected to listen and act more than speak. So today I am violating several key Aleut tenets. But my immediate family, my extended family, the elders, and the leaders of my community have trained me since childhood to have a foot in two worlds. They knew that one day the world would be ready to listen and learn about the value and importance of sharing knowledge and experience between different cultures. My topic—ocean use in a traditional society—is a particularly challenging one, even for one such as myself, raised in a very traditional Aleut way, and coming from a people who have been in the Bering Sea for almost 10,000 years.

It is easy to describe how we depend upon the Bering Sea and to list the kinds of fish and wildlife we use, but it's not as easy to articulate the meaning of this way of life so that others can understand and appreciate it. Much of the difficulty comes, I believe, from the perceived necessity for those in Western societies to define almost everything as a way to understand, while the meaning of things in coastal cultures comes not from words and how they're used but from feelings in the contexts of interactions and cultures. This is why words always fall far short of explaining major aspects of coastal cultures and indeed indigenous cultures around the world.

Before talking about Alaska Native coastal cultures and our relationship with the sea, it would be appropriate to briefly contrast the world views and communication styles of such cultures and that of Western societies. Alaska Native coastal cultures do not define things; Western society defines most everything. To understand the environment, coastal cultures view the world in terms of connections; Western society breaks things down into component parts. Coastal cultures teach more by action than by words; Western society teaches by words. Coastal cultures use indirect approaches to resolve conflict; Western society uses direct confrontation to resolve conflict. Coastal cultures are group-oriented; Western society is individual-oriented. Coastal cultures are defined by the natural environment; in Western society, to a large degree, the natural environment is defined by the cultural environment. Coastal cultures believe nature cannot be controlled; Western society, to a large degree, believes that nature can be controlled. Coastal cultures adapt through natural changes; Western society adapts nature to human changes. Coastal cultures are visually oriented; Western cultures are thought-oriented. Coastal cultures use communal pressure to obtain individual conformance to societal norms; Western society frequently uses punitive measures defined in written law. Coastal cultures transfer knowledge and experience orally; Western society transfers knowledge and experience through written means. Coastal cultures teach respect for wildlife and nature through language, culture, way of life, and direct interactions; Western society teaches respect through moral principles and indirect interactions. Coastal cultures make a point by telling stories; in Western society, you're expected to make a point directly. Coastal cultures are qualitative in description of nature's parts, whereas Western society is quantitative. Last but not least, coastal cultures' world view is organic and circular, and I hope to describe some of the way this is; whereas Western society's world view is mechanistic and linear.

Although coastal communities vary in the application of the principles and paradigms I've just enumerated, and I probably left out many principles, this list highlights some of the fundamental differences in world views between Western society and coastal cultures. Therein lies a challenge for people in both worlds who sincerely try to bridge the gaps of understanding, respect, and appreciation of value.

A colleague of mine for 13 years, Susanne Swibold, an artist and a research associate with the Arctic Institute of North America in Canada, once articulated an artist's world view, which I'd like to quote:

> The artist is willing and not uncomfortable in exploring the unknown, the untried. The artist's process is to bring unity within diversity, to establish a dynamic equilibrium, which is a harmony of diverse parts. This is a beauty. In the process, the artist looks deeply into the institutional group and organizational forms and finds a way to release the spirit within. When set free, the possible is realized and set in motion. To the artist, our world is alive, creative and diversified because there is unity of its parts which are inseparable and exist in a dynamic equilibrium-seeking process. It contains elements of unpredictability and constant motion. There are no solutions to this movement. Man can respond to this through the process of creative looking, listening and thinking that requires a sense of adventure and courage. Humankind's place in that unpredictability must be one of humility as one element among many in the dynamic forces of nature. When we seek to understand how nature's systems behave, we may realize the inherent value of living in a world that moves beyond our control. This dynamic living in the world that continually seeks equilibrium in mysterious ways to ensure life enriches and stimulates our curiosity and our wonder and nourishes our spirits in wisdom and grace.

I think Swibold's articulation of an artist's world view strikingly describes some of the coastal culture world view and that of many indigenous cultures throughout the world which have had sustained and intimate contact with their immediate environment for generations. Yet both artists and indigenous peoples have little stature in our society and no legitimized role in human problem-solving. Indigenous peoples and artists are placed in the margins of acceptance by people in decision-making hierarchies in Western society. This condition, I believe, is a direct result of a lack of understanding, the lack of a process to enhance understanding, and a lack of critical thinking that is endemic throughout most institutional frameworks in industrialized societies, conditions which may ultimately spell our demise unless we see how different world views can complement and supplement the human quest for not just survival, but qualitative survival.

I'd like to cite some real-life examples which demonstrate in microcosm how this lack of understanding and critical thinking commonly manifests itself in the interaction—or, perhaps more appropriately the lack of interaction—between indigenous peoples and those from societies who practice linear mechanistic world views, and to point out some of the practical consequences of this.

For over a hundred years, scientists and researchers have been going to the Pribilof Islands, which are located in the middle of the Bering Sea, to the home of the largest Aleut community in world, which is on St. Paul, my home town, to study fur seals. Bird scientists have been visiting the Pribilofs to study sea birds for over three decades. In this last century, hundreds of scientists and researchers have visited this "Galapagos of the North," as we call it. As a result, there's probably no other indigenous community in Alaska—or in the entire Northern Hemisphere, for that matter—which has had such extensive and sustained contact with Western science, or which is affected more by the results of their work than Pribilof Aleuts, and as such it may be a good case study of indigenous peoples and Western science and researcher contact.

Toward the latter part of the 1950s, fur seal researchers and managers decided to conduct a herd reduction program. To do this, they grafted a California ungulate herd reduction formula onto the fur seal, which called for culling females. The Pribilof Aleuts—at the time a captive labor force of the U.S. government to harvest fur seals—refused to kill female seals. Essentially, the Aleuts were conducting a strike against the U.S. government. The Pribilof Aleuts understood that killing a female was not killing one seal but three: the pup she was carrying at the time, the pup that she would become impregnated with shortly after delivery, and the female herself. In addition, the Aleut people understood there was no way in the world anyone could predict the percentage of pups that would be born which would also be female. It never dawned on the fur seal researchers and managers to include in their herd reduction model factors which adjusted for major differences between ungulates and fur seals.

At any rate, the managers did not listen to the Aleut warnings about killing females. They forced the Aleut men to kill the females under threat of loss of home, loss of job, or deportation off the island. The results were as predictable as they were disastrous. The fur seal population plummeted and their reproductive capacity was substantially reduced. This is part of the reason why today the Pribilof fur seal herd is 40% of its peak population in the late 1950s, and the herd is not growing today. Also, the male seals, which used to average 20 to 50 females in their harems in the late 1950s, now average 10 to 20, if any at all.

In another example, during the 1970s and 1980s, the Pribilof Aleut people told the scientists, the researchers, the managers, and the policy makers in numerous forums their concern about observations of wildlife behavior and conditions in the Pribilofs. Chicks were too weak to maintain their hold on cliff ledges, so they fell to their deaths. Sea lions were chasing and eating seal pups in greater numbers than ever in living memory. When fur seal pelts were fleshed and shown up to the light, the light would shine through. Again, this was something that we had never seen or recorded in living memory.

Now, these observations told Pribilof Aleuts that there was something gravely amiss in the Bering Sea ecosystem. And that food stress was evident. The women told us that the bird breastbones were protruding quite unusually, and their breast muscles were collapsed. We sounded this alarm in numerous forums to no avail.

Western scientific inquiry and decision-making processes were and are fragmented, highly specialized, and not geared to evaluate connections between different environmental components. Aleut observations were and still are labeled anecdotal. Because they are not based on gathering numerical data sets over time, Aleut observations cannot be validated by linear-based formulas used in computer model simulations. These are constructs used by all natural resource managers in industrialized societies, constructs that disenfranchise and marginalize indigenous peoples throughout the world, peoples whose cultures evolved from nature's dictates.

As a slight departure, this may be a good time to evaluate how nature's dictates are viewed by many coastal cultures. I am generalizing, and as with all generalizations there are exceptions and differences. There are, however, common threads for those coastal cultures that have intimate and sustained contact with their immediate environment for generations. For such cultures, defining nature's parts creates not understanding, but diminishes it and the human spiritual connection to it. For these cultures, nature is viewed as organic, chaotic, always in a state of flux, dynamic and synergistic in its interactions: where the only constant is change, where everything and all creation is connected, where the spiritual and the physical are inseparable, where no single part is more important than any other, where humility is required in the face of nature's awesome dynamic properties, where the whole is greater than the sum of its parts, where humans must practice a life of reciprocity if humans are to be ultimately sustained. That is nature.

Now, back to the Pribilofs. Fur seals were classified as depleted in 1987 under the U.S. Marine Mammal Protection Act. Sea lions were classified as threatened under the Endangered Species Act of 1990. In that same year, Bering Sea scientists gathered at the University of Alaska in the "Is it Food?" conference concluded that it was probably food stress causing the precipitous declines. Originally in the 1970s, we had flagged four species; we now flagged 20 species in a state of severe and sustained decline in the Bering Sea. In 1991, Russian scientific research through Dr. Alexander Golovkin, sponsored by Pribilof Aleuts, documented an 83% decline in four key seabird species in the Pribilofs. These determinations had been made by Pribilof Aleuts more than a decade earlier.

It gives Pribilof Aleuts little consolation to say, "We told you so."

These examples of contact between the Aleuts and Western scientists and managers that I've just cited are only two of dozens of such examples from the Pribilof Islands, and it is not atypical of the interactions or contact between Western science researchers and managers and Native peoples around the world. I can tell you, for example, how Western researchers documented only five colonies of least auklets on St. Paul Island after 20 years of research, and how our eight-, nine-, and ten-year-old children proved that there were in fact 15 colonies after a Russian scientist, unconstrained by conventional wisdom, asked the children. He understood that Aleut hunting ethics began with hunting least auklets at a very early age.

I can tell you about how one researcher recently spent thousands of dollars to study fur seal vocalizations, but never thought to ask the people who have lived with the seals for nearly 10,000 years about those vocalizations. I can tell you of how the University of California spent some

$300,000 to pay for a submersible to determine whether or not halibut foraged off the sea bottom. Any 11-year-old on St. Paul could prove unequivocally not only that halibut do forage off the sea bottom, but the specific conditions under which they forage off the sea bottom, something that was not assessed by this $300,000 study.

I don't want to belabor the point, nor do I wish to convey the impression that indigenous knowledge is better than Western science. Indeed, my elders teach me—and that is the spirit in which I am trying to convey this—that when we interact with people we must do so with love, in the hopes of creating greater understanding and respect for each other.

There are three salient points out of these examples. One, until institutions and professions in industrialized societies make it safe and acceptable to recognize indigenous knowledge and experience, we will never create a functional bridge between different world views and Native world views will continue to be marginalized. Two, by not acknowledging indigenous knowledge and experience such knowledge, experience, ways of life, and culture are unwittingly being eroded and destroyed in countless subtle but significant ways. It's a simple step, for example, for young impressionable indigenous persons to see that the ways of the elders and ancestors are ignored in the society in which they are expected to make their future, and they act accordingly. Many young people also begin to ignore the influence of elders in terms of how to treat animals, because such influence is not recognized by—and instead is replaced by—outside enforcement of laws that are based on punitive measures in order to control human behavior.

The third point is perhaps the most salient. Because of the innumerable subtle ways in which cultures are eroded and destroyed, the world is rapidly becoming a monoculture in terms of agricultural systems, energy use, clothing, education, science, economics, mathematics, and ways of knowing. Our world views are narrowing at a frightening pace. I mentioned how indigenous peoples and artists are marginalized. By the same token, there is a systemic pattern of diminishing support for independent researchers who may have fresh perspectives on human problems. Industrialized societies also marginalize the world views of women, views which contribute to the intuitive and emotional sense, and the process orientation lacking in male-dominated, top-down control, and goal-oriented, logic-focused systems. From what I can see, out of about 60 people here today, maybe 10 or 12 are women.

This is a dangerous situation for humans because this trend diminishes the potential for creativity at a time in our history when we desperately need to release our creativity to address the daunting human problems in dealing with the environment.

Our failure to successfully address these challenges does not mean the absolute destruction of nature—remember the humility factor. Nature is far more forceful than that. It will survive way beyond the human race, no matter what we do to it. Our failure will ensure the eventual demise not of nature, but of the human race.

If we believe these challenges are too daunting, too huge, and too overwhelming, then that will be a self-fulfilling prophecy. Whoever believes that a single individual cannot make a difference on these issues contributes to our ultimate demise. For those folks, I have only one good advice left: prepare your progeny to live a life of dignity in a world of great suffering and eventual terminal illness, spiritually and physically.

At this point, you should be able to surmise my concept of an ideal program, although it's not a panacea, to take the first steps in dealing with any and all human problems, at least at the institutional and governmental level. Bring together not an interdisciplinary but a transdisciplinary, cross-cultural gender-equal group, unconstrained by conventional wisdom and hierarchical structures, add elements of spirituality and humility, a willingness to explore new paradigms with the understanding that to focus on any human problem we must deal with chaos, not order or predictability, and we will have the beginnings of a true creative revolution.

I ask you, as leaders of Western society's bastions of higher learning, to consider taking a mental leap into an exciting unknown. If you do, I for one, and I'm sure there are going to be many others, would be willing to be a part of it.

DISCUSSION

*(**Carol Reinisch**, Tufts Veterinary School)*

You've raised a number of very complex issues. In terms of dealing with issues of human health, one of the things many of us face now, as heads of institutions or departments, is the mandatory inclusion by the National Institute of Health of all populations in the United States of particular *minorities, of Native Americans, and so forth. How do we change our thinking, learn to include different populations in a manner which is equal and is not necessarily top-down or mandatory?*

Merculieff. It is a very difficult challenge, but not impossible. One of the ways we approach dealing with people of different ways of looking at things is to establish a forum or a gathering, no matter what level or how many may be involved, where consensus is adopted as the absolute principle. You do not leave the room until all are agreed as to what should be done. Frequently this is a very painful and drawn out process, but you save decades of effort trying to bring people together if you spend a few years adopting this principle of consensus. That's one approach.

It's not the only approach. If we take people from different world views unconstrained by conventional wisdom, the creative process is quite unbelievable. I want to mention along those lines that my colleague, Susanne Swibold, has developed a plan to tackle the daunting issues in the Bering Sea based on these principles. It's not a model, because by the time scientists put together the data sets to create a model, the environment has changed and the model is no good. Instead, Swibold's plan looks at the processes. The processes are the key to arriving at solutions. It should not be goal-oriented; it should be process-oriented.

(**Valery Petrosyan**, *University of Moscow.*)

I'm a professor of chemistry, but my question deals more with my activities in the field of environmental education, as director of Open Ecological University in Moscow, and stems from my interest in the level of environmental education and environmental culture in small communities like yours. What can you tell us about the level of environmental education and environmental culture of the people in your community?

Merculieff. Aleut people, like most indigenous peoples throughout the world, are facing the rapid erosion of their culture, way of life, and world view. This is done in countless subtle but very significant ways. One example is the introduction of television. In Western society, television programming is very fast-paced, including the advertisements. Scenes change constantly and there is constant narration or music in the background. This simple thing has perhaps done more to erode indigenous cultures than anything else. In Aleut culture, the way we understand and relate to the environment takes a great deal of patience. We sit in one place for hours, days on end, weeks on end, year after year. The fast movement in television programming teaches the young people impatience. The critical thinking, the creativity, that is essential for cultural sustainability is diminished both by the constant narration and the background music—which manipulates emotion, thereby not allowing one to feel what one genuinely feels. This is certainly true of environmental education films in the United States, which have authority figures who speak in the background explaining what one is seeing. When young people are exposed to that, they learn to relinquish their own thought processes for those of the authority figure. I can cite hundreds of examples. I could do an entire course on how cultural erosion takes place in subtle ways.

We are now trying to revitalize our cultural system, an effort which requires an extensive relationship with elders and mentors in practical action, rather than classroom teaching. In the end, this has to be the way we teach human beings' role in all creation.

(**Robert White**, *University of Alaska Fairbanks.*)

How would a Native group of people get a better acceptance of a finding? Let's say we're discussing management of some animal populations. We have a Western finding that shows the population is increasing, but a local group of people think the population is not increasing because where they are there are no animals. The Western scientists have a very good data set and of course the local people's knowledge is also exactly right—there are no animals in that area now. Can you see the way in which we get together and accept each other's opinions and progress to the next step?

Merculieff. Before we come to the point of acceptance of conclusions made by anyone from a particular society, we must focus on the process. It will be a long time to work out this process in a spirit of reciprocity and mutual respect about how we can begin to work together so that eventually trust is developed. It will take many years. But whether or not it ever develops depends on how sincere the process is from the outset. Cross-cultural communications mechanisms and the awareness of differences in communication styles have to be the beginnings of beginning to relate to each other.

I was recently at Chalkyitsik, a traditional village northeast of Fairbanks. The people are mostly subsistence-oriented; they live off the land and the river. There was a gathering of chiefs from seven different areas in that interior part of Alaska.

They were gathered there to listen to a Western scientific manager explain how his team had concluded that moose populations were declining. He went through a 45-minute dissertation about how they were doing aerial transects and counting male-to-female bull ratios. After the presentation, the head chief asked, "Sir, did you notice that the river levels are going down?"

The manager said, "No, we didn't; we're doing aerial moose counts."

"Well, do you know that when the river level goes down, the top portions of the plants that the moose forage on die?"

"No, I didn't know that."

"Well, did you notice that there are 20 beaver dams in the area?"

"No, that is another component of research in my department. We do not study beavers, we do male and female bull counts for moose."

You could feel the frustration—and the development of distrust that was occurring as a result of that frustration—when both parties sincerely tried to communicate without necessary tools. The process is going to be absolutely key.

(**John Kelley**, *University of Alaska Fairbanks.)*

Of the many very excellent remarks you made this morning, two strike me as being extremely important. The first one was your remark about the number of observations of the natural environment in your home territory that have been made over many decades. I would like to extend that to just about everywhere along the coast, whether it be Canada, the United States, or Siberia. The second point was the word willingness you used for indigenous Native groups to get together and try to effect a better communication with the scientific community. I consider this to be extremely important. The willingness is there, but the mechanism eludes us. I have served for more than a decade on an advisory committee for the North Slope Borough, and we make no progress in being able to effect that very, very important interpersonal communication. Do you have any wisdom to share with us at this sort of primitive level as to how we might really do this?

Merculieff. I can tell you of one approach we used in the Pribilof Islands. First of all, we had to recruit scientists from Russia because they did not have a vested interest in the systems that were set up for research in the Bering Sea and on the Pribilof Islands; a vested interest colors the perspective and indeed the interaction between scientists and Native peoples. We decided to discuss the value of local knowledge, and then to simulate a situation where the scientists could interact in a meaningful fashion with the local people. The scientists were marine researchers studying the status of the Bering Sea ecosystem, all on a mesoscale. A mesoscale analysis of an ecosystem-wide condition had never been done in the Bering Sea. They agreed to try the Aleut philosophy that everything is connected—that mesoscale activities may in fact be indicators of the macroscale in the Bering Sea. Lo and behold, after three years of effort, they have concluded that, yes, this is in fact true.

Before conducting their research, they had to identify the areas that were most productive on the mesoscale. They brought together all the subsistence fishers and asked them where they saw most of the birds gathering, at what time of year, where did they catch the most halibut, where did they see the most crabbing activities. They went to that spot and began their transects. That saved them many, many years. Through this specific action-oriented program, mutual trust was developed between the scientists and the Aleut people. And now our people are saying, "Come back, come back, come back." That is unheard of between scientists and Native peoples, you must admit. If we can create a forum to creatively explore how to do this, we can come up with ways appropriate for every single group.

(**Tony Pitcher**, *University of British Columbia.)*

The knowledge of the local people, the Native cultures around the rim of the Pacific from the Philippines, Sumatra, Chiloe Island in Chile, some of the Japanese coastal fishing communities, and now in the Aleutians, can enhance the scientific knowledge of people like me.

There's a way forward through community management. In British Columbia now, some of the Native peoples are involved in managing salmon and shellfish resources on the coast. On a small scale, we have models for the future of the ways we can manage these communities. Can you give us any insight on how we can deal with those massive vested interests, the huge multinational super-governmental economic pressures that are driving the exploitation of our resources in the Pacific, particularly in the Bering Sea?

Merculieff. If we can find a creative way to appeal to the self-interest of the megascale fishery activities and the huge capitalized high-tech fishing vessel owners, then we begin to find solutions. One of the things Aleut people understand very well is that you cannot separate the human from the environment. We are part and parcel of it, including our economic activities. The question is not sustainable development, but sustainable environment. If we can use that principle and find ways to appeal to the self-interest of those user groups, we'll be able to develop the semblance of some cooperative resolution. That's very general, I know. We are working on some specific areas dealing with the Bering Sea, but it would take too long to discuss here. If you wish to explore any of these concepts more in-depth in work sessions, workshops, and conferences—any speaking or exchange forum—my colleague, Susanne Swibold, and I do this around the world.

Economics of Resource Use: A Bioeconomic Analysis of the Pacific Halibut Fishery

Keith R. Criddle
University of Alaska Fairbanks
Fairbanks, Alaska, U.S.A.

INTRODUCTION

Although most commercially important marine fish stocks occur within the extended jurisdictions of various coastal nations, and although extended jurisdictions have been established for nearly fifteen years, many of these stocks are considered depressed. Why have coastal governments failed in their trusteeship over fishery resources? Through focusing on the incentives faced by individual fishers, the field of economics provides insight into the factors that contribute to the current mismanagement of fisheries, predicts the response of individuals to alternative management policies, and suggests strategies that are more likely to result in the responsible management of these public trust resources. In this article, the application of economic analysis of resource use is illustrated using a simulation-optimization model based on the commercial fishery for Pacific halibut, *Hippoglossus stenolepis*, off the western coasts of the United States and Canada.

Commercial harvests of Pacific halibut began off the coasts of Oregon, Washington, and British Columbia in the late 1800s and spread into the Gulf of Alaska by the early 1900s. By 1935, landings of halibut had climbed above 47 million pounds. This explosive expansion of effort and catches is characteristic of the discovery and initial exploitation of a virgin natural resource.

At the inception of the commercial fishery, the exploitable biomass of halibut was approximately 586 million pounds. By 1935, this stock had been reduced to 159 million pounds. In 1923, motivated by concern for the long-term viability of the halibut resource, the U.S. and Canadian governments entered into a treaty agreement which led to the formation of the International Pacific Halibut Commission (IPHC). For the past 70 years, the IPHC has had primary responsibility for the conservation and management of halibut in the Northeast Pacific Ocean. Between 1935 and 1959, the stock of halibut nearly doubled, reaching a peak of 307 million pounds. Then, over the following 14 years, the stock crashed to a biomass of 128 million pounds. By 1989, the exploitable biomass had risen to 332 million pounds (Figure 1). In most years, total removals of halibut have equaled or exceeded target levels specified by the IPHC.

The IPHC has the authority to regulate total removals of halibut in U.S. and Canadian waters. Total removals are the sum of legal commercial catches, incidental and illegal catches, and sportfishing catches. Between 1935 and 1992, the total removal of halibut averaged 60.8 million pounds and varied between 21 and 75 million pounds (Figure 2). Although total removals have approximately paralleled trends in exploitable biomass, the correspondence has not been exact (Figure 1). In most years, total removals of halibut have equated or exceeded target levels specified by the IPHC.

The problem is that fishers want more fish than nature can provide. Because the capacity to harvest halibut exceeds the minimum required to fully exploit the total allowable catch (TAC), managers must select a mechanism for allocating the scarce resource among competing claimants. The allocation of halibut occurs at two levels. The first allocation is between the commercial halibut fishery, the sportfish and subsistence fisheries, and the commercial fisheries for other species of groundfish who incidentally harvest some halibut. Allocations between user groups are usually determined through a political process. A second allocation occurs among the members of each user group. In the United States, the traditional mechanism for allocating halibut among competing fishers within user groups is the "derby"—a brief opening of the fishery during which intense fishing occurs.

A focus on the relationship between total removals and stock biomass may suffice for describing the effect of management decisions on the resource stock; however, it is inadequate as a

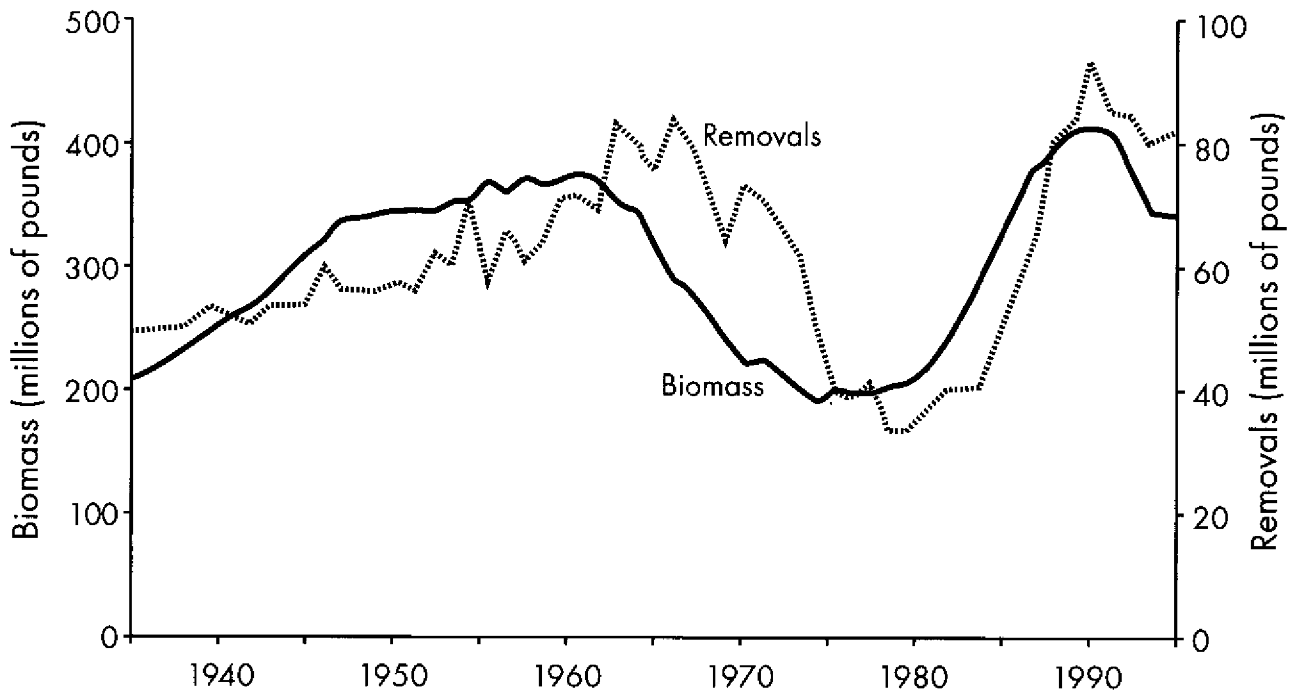


Figure 1. Biomass and catches of halibut from the northeast Pacific Ocean.

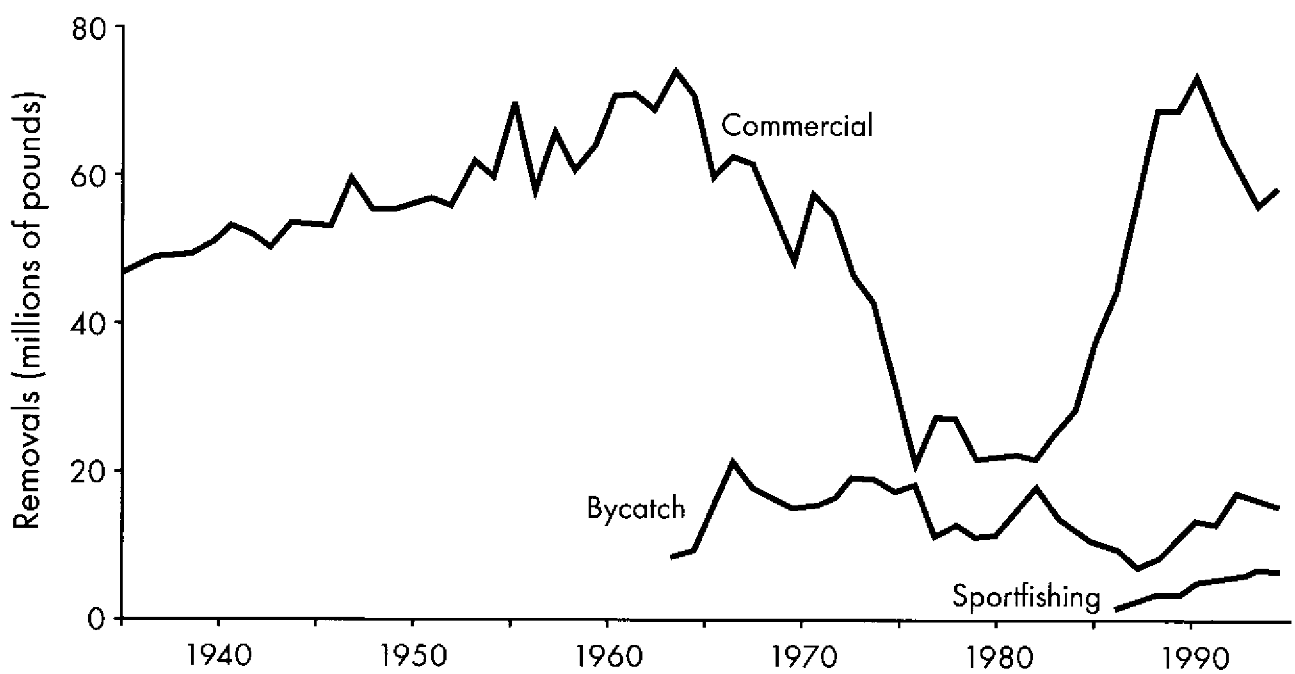


Figure 2. Removals of halibut from the northeast Pacific Ocean.

measure of the impact of management decisions on resource users. Thus, it provides no insight into the manner in which fishers will respond to management policies.

To predict how fishers will respond to changes in management policies, it is first necessary to consider the incentives that motivate them. For commercial fishers, these incentives include the opportunity to profit from fishing. In order to obtain revenue from the sales of halibut, fishers must incur the costs of catching halibut. Profit is the difference between gross revenues and costs, and depends on the ex-vessel price offered by processors, the quantity of fish landed, and the cost and amount of effort used in fishing. Changes in the costs of fishing or in the ex-vessel price offered for halibut influence the individual and collective behavior of commercial fishers.

Because processors bid against each other for shares of the commercial landings, it can be anticipated that there is an inverse relationship between the magnitude of landings and the prices offered to fishers; when the quantity of halibut landed is high, prices tend to be low, and when the commercial catch is low, the ex-vessel price is bid up by the processors. Figure 3 depicts the time series of commercial landings and ex-vessel prices for 1935–1992. (To eliminate the effect of general changes in the prices of goods and services—inflation—all monetary values are adjusted to 1982 levels using the implicit GNP deflator. To recover price levels for 1992, multiply the reported values by 1.22.) The ex-vessel price has averaged $0.97 per pound with little variation other than during the late 1970s and early 1980s when the ex-vessel price climbed to $2.13 per pound. This period of high prices corresponds to a period of small commercial catches. Because the gross earnings of fishers are the product of their catches and the ex-vessel price, the gross value of commercial landings of halibut has remained relatively constant with an average value of $47.2 million (Figure 4).

Although there is little direct information about the cost of commercial fishing, estimates of the level of participation in the fishery are available. Figure 5 represents the number of standardized units of effort employed in the halibut fishery between 1974 and 1992.

A SIMULATION-OPTIMIZATION MODEL OF THE PACIFIC HALIBUT FISHERY

Bioeconomic simulation-optimization models consist of three interlinked components: an objective function, a description of the biological system, and a description of economic relationships.

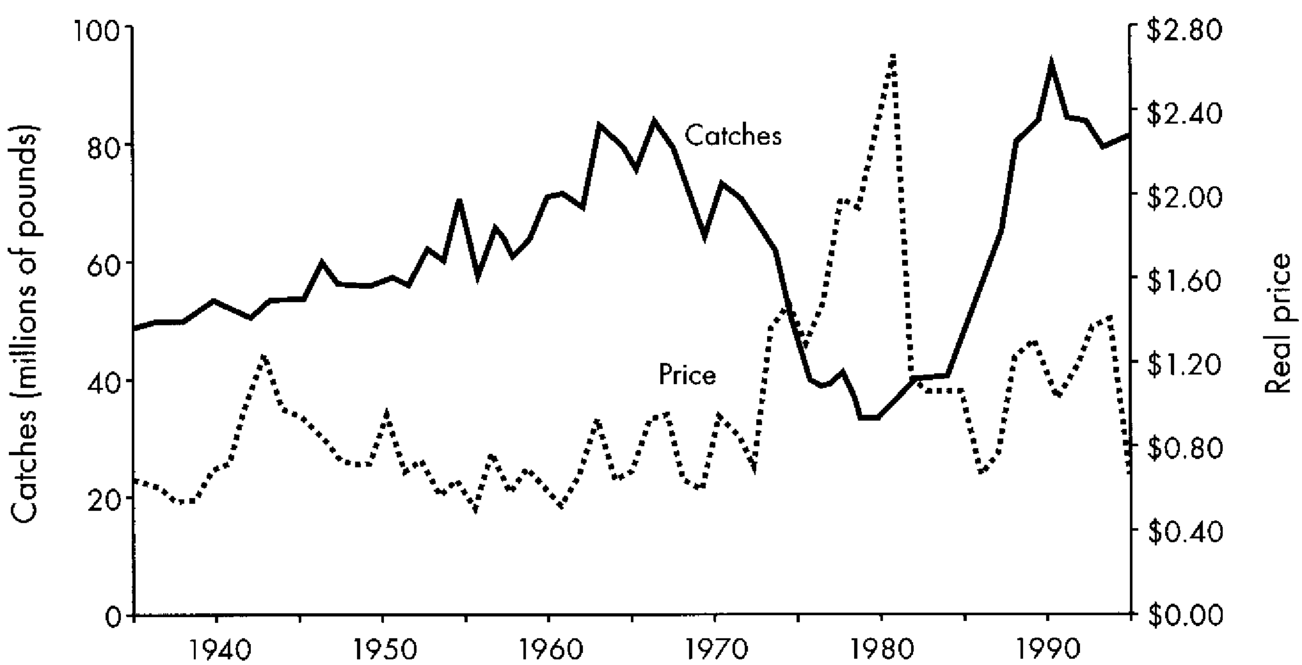


Figure 3. Catches and prices of halibut in the northeast Pacific Ocean.

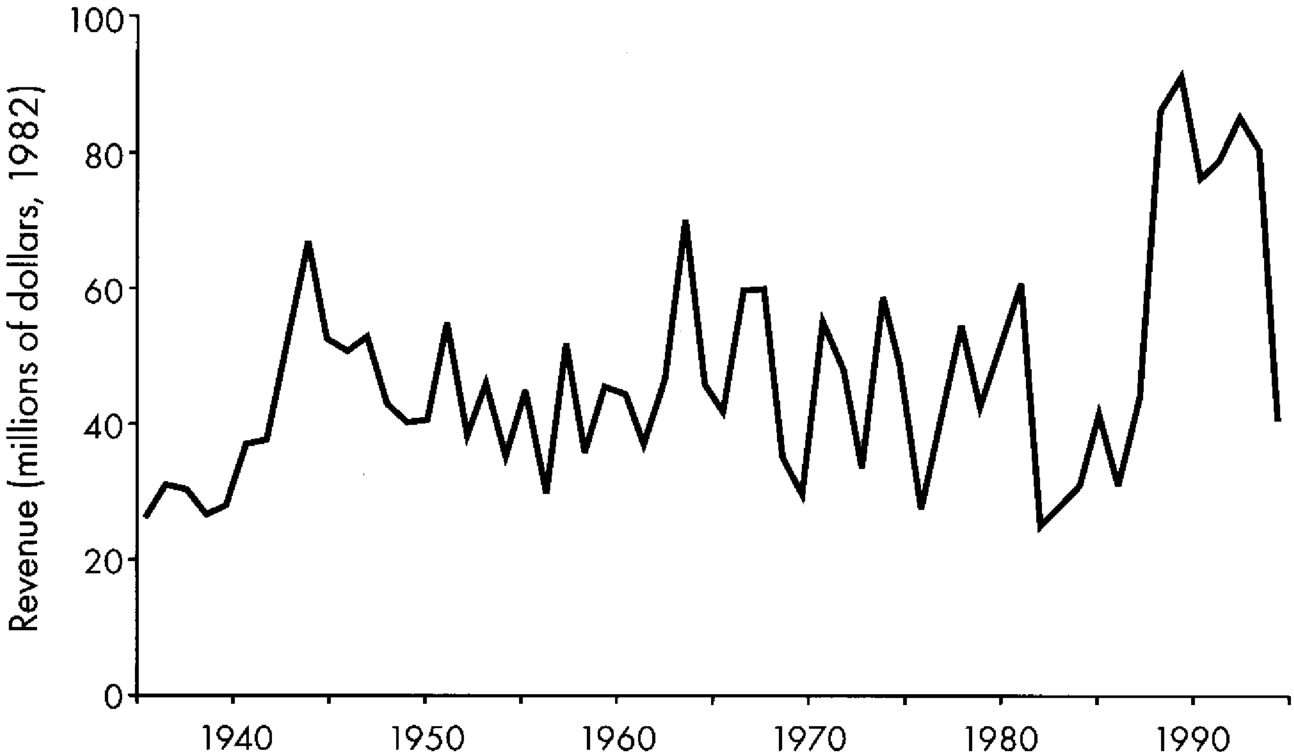


Figure 4. Gross revenues in the northeast Pacific Ocean halibut fishery.

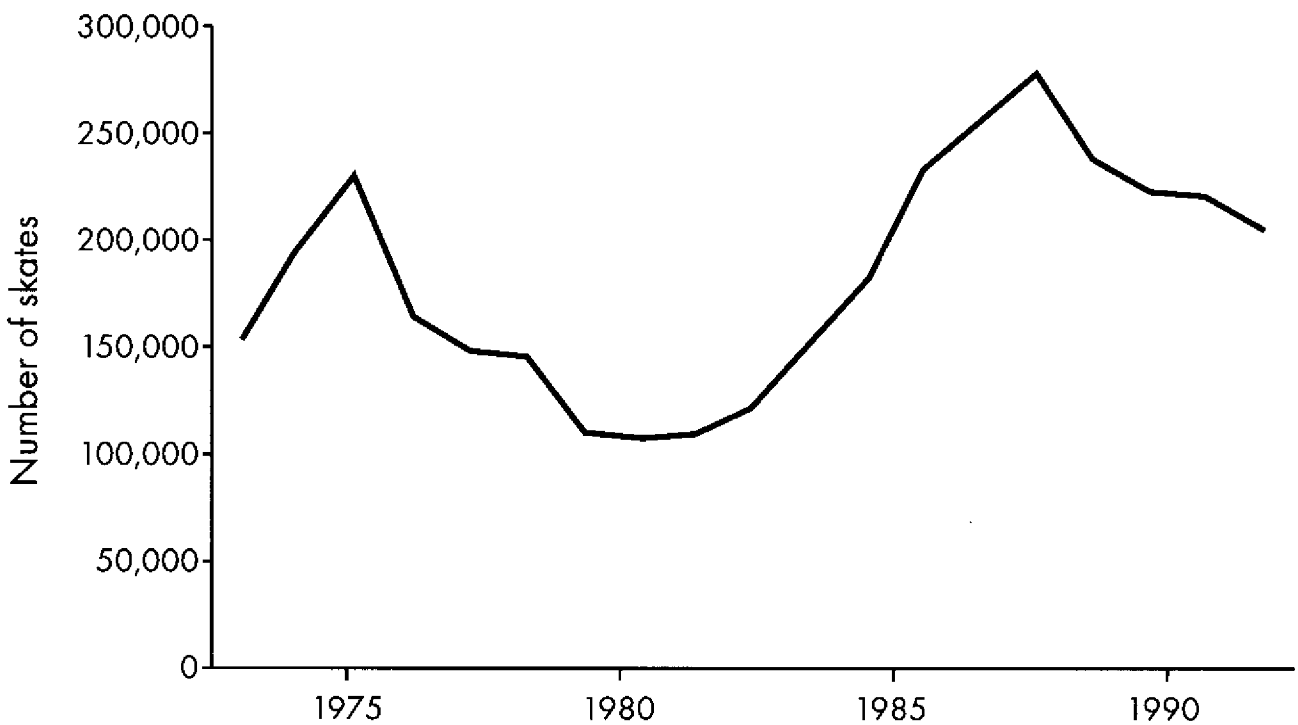


Figure 5. Fishing effort used to catch halibut in the northeast Pacific Ocean.

Specification of an objective function is a subjective process and reflects the interests of resource managers and their constituents. The enabling legislation that creates a management agency may task that agency with specific (and occasionally conflicting) objectives. In many instances, the objectives that managers apparently pursue differ from their stated goals. One objective that is frequently identified for fisheries management is the maximization of sustainable yields (MSY). Because costs are incurred in harvesting of natural resources, economists suggest the maximization of sustainable net revenues (MEY). Although responsibility for management of fishery resources is almost invariably retained by government agencies, the actual exploitation of these resources is generally conducted by private individuals or corporations. The mechanism employed to allocate catches within the commercial fishery can have important implications for the pattern of resource use that would emerge in the absence of management constraints. When catches are allocated on a derby basis, fishers respond in a characteristic manner referred to by Hardin (1968) as the "tragedy of the commons" and referred to below as the open access solution (OA).

The Demand Curve

Economic theory suggests that prices should depend on the total quantity produced, and on the prices of substitute and complementary goods. For expository purposes, these refinements will be ignored, and the historic combinations of price and quantity will be assumed to reflect shifts in the supply function (due to changes in the TAC) with a constant ex-vessel demand function. The estimated relationship between ex-vessel price and commercial catches is:

$$(1)\quad P_t = \$1.915 - 0.018h_t \qquad F_{(1,56)} = 10.156$$

where P_t and h_t are respectively the ex-vessel price and commercial landings of halibut in year t. The estimated demand curve indicates that the price of halibut declines at a rate of about two cents for each one million pounds of halibut landed in the commercial fishery. Observed prices (normalized to constant 1982 levels) and the estimated demand curve are represented in Figure 6.

Halibut Population Dynamics

The biomass of an age class of fish changes over time as a result of growth, predation, other natural mortality, and harvesting. Since observations on increments and decrements to populations are discrete, population dynamics can be represented as a vector difference equation

$$(2)\quad x_t = g(x_{t-1}, x_{t-2}, \ldots) - m_{t-1} - p_{t-1} + r_{t-1} - h_{t-1}.$$

Biomass (x_t) is a function of lagged biomass and physical-oceanographic factors such as temperature and salinity through the growth function $g(\bullet)$, recruitment as a result of past reproduction r_{t-1}, predation and cannibalism p_{t-1}, other natural mortality m_{t-1}, and harvesting h_{t-1}.

Unfortunately, while harvesting is observable and current biomass can be sampled, natural mortality, predation, and recruitment are latent variables. Criddle (1991) and Criddle and Havenner (1991) discuss two approaches to formally treat these unobservable effects—approximate structural models and time series models. Although the time series and hybrid structural-time series approaches are generally preferred to pure structural representations, the structural approach is easier to represent.

In the structural approach, unobservables are related to present and past observables

$$(3)\quad \begin{pmatrix} m_t \\ p_t \\ r_t \end{pmatrix} = \boldsymbol{f}(x_{t-1}, x_{t-2}, \ldots)$$

where the vector valued function $\boldsymbol{f}$ also incorporates influences such as sea surface temperature. Solving equation (3) for individual effects and substituting the result into equation (2) provides a model specified strictly in terms of observable variables:

$$(4)\quad \begin{aligned} x_t &= g(x_{t-1}, x_{t-2}, \ldots) - m(x_{t-1}, x_{t-2}, \ldots) \\ &\quad - p(x_{t-1}, x_{t-2}, \ldots) + r(x_{t-1}, x_{t-2}, \ldots) - h_{t-1} \\ &= \boldsymbol{f}(x_{t-1}, x_{t-2}, \ldots) - h_{t-1} \end{aligned}$$

where the function $\boldsymbol{f}$ has been implicitly redefined.

To use the model in equation (4), the form of $\boldsymbol{f}$ must be explicitly assumed, a priori. One of the simplest specifications of $\boldsymbol{f}$ is the Pearl-Verhulst or logistic model (Schaefer, 1954). A discrete representation of the model can be written as a quadratic first order difference equation:

$$(5)\quad \begin{aligned} x_t &= (1+g)x_{t-1} - \frac{g}{k}x_{t-1}^2 - h_{t-1} \\ &= \beta_1 x_{t-1} - \beta_2 x_{t-1}^2 - h_{t-1} \end{aligned}$$

where g and k are the intrinsic growth rate and carrying capacity, and β_1 and β_2 are implicitly defined. The estimated model is:

$$(6)\quad \begin{aligned} &x_t = 1.461x_{t-1} - 0.0008x_{t-1}^2 - h_{t-1} \\ &F_{(1,55)} = 1{,}090.2 \end{aligned}$$

Although this model is incapable of representing dynamics at lags beyond one time-step, the effects of variation in physical-oceanographic factors, or interactions among age-classes or between species, it is able to account for most of the past variations in the biomass of halibut. The fit of the estimated model to the observed levels of biomass can be seen in Figure 7, while the model's dynamic properties are represented in Figure 8.

Sustainable Yields

Sustainable yields are catches that just offset the intrinsic rate of growth and vary as a function of biomass

$$(7)\quad h_{SY} = 0.461x - 0.0008x^2.$$

Figure 9 illustrates the relationship between biomass, catch, and sustainable yields for 1935-1992. When catches have exceeded sustainable yields, the biomass of halibut has declined.

Figure 10 depicts the inherent dynamics of the variation in sustainable yields as a function of biomass. Catches below the sustainable yield curve allow biomass to increase, while catches above the sustainable yield curve will cause biomass to decline. The MSY for halibut in the Northeast Pacific is estimated to be 67.6 million pounds at a biomass of 293 million pounds (see also Table 1 below).

Input Requirements

The amount of effort required to harvest the sustainable yields depends in a complicated manner on catch and biomass

$$(8)\quad e_t = 6.68h_t^{1.279}x_t^{-1.518} \qquad F_{(2,16)} = 35.9.$$

That is, the effort (e_t) required to harvest the sustainable yield declines as the biomass increases, but increases as the number of fish harvested increases. The relationship between the effort and biomass is shown in Figure 11.

The Cost Function

In the long run, firms participating in the fishery must not only be able to cover the variable costs incurred on each trip (bait, fuel, food, fishing gear, crew compensation, etc.) but also the cost of maintaining and replacing their durable capital (hull, engine, electronics) and the opportunity cost of their time and capital investments. Even if firms cannot cover all of their long-run costs, they may continue to participate in the fishery as long as they can at least cover their trip costs. Variable trip costs are about \$100 per skate (NPFMC, 1991).

The Northeast Pacific halibut fishery was managed on a derby-based system from 1935 through 1990. The Canadian segment of the fishery (40%) has been managed under an individual vessel quota system since 1991. Although the U.S. fishery has continued to be managed on a derby basis, the Alaskan portion of the U.S. fishery is also scheduled to be managed on an individual quota share system beginning in 1995.

Economic theory suggests that under a derby-based allocation system, the expected value of long-run average profits is zero. Average gross revenue over the most recent 19 years has been \$293.02 per skate. It will be assumed that the long-run total costs can be separated from variable trip costs, that they can be linearly apportioned to effort, and that they identically exhaust expected revenues, that is:

$$(9)\quad TC_t = \$100e_t + \$193.02e_t = \$293.02e_t.$$

RESULTS

Model equations (1), (6), (7), (8), and (9) were used to estimate effort, catch, price, total revenue, and total costs for biomass levels between 0 and 586 million pounds. The results were then examined for the static solutions under MSY, MEY, and open access criteria. (See Criddle, 1992 for the solution to a dynamic bioeconomic model.) The long-run baseline solution is represented in Figures 12a-c, and in Table 1. Long-run and short-run solutions are contrasted in Figures 13a-c, and in Table 1. The effects of an enduring ex-vessel price increase are depicted in Figures 14a-c, and in Table 1.

Harvesting the maximum sustainable yield requires an effort level of about 260,000 skates (Figure 12a). The long-run cost of fishing 260,000

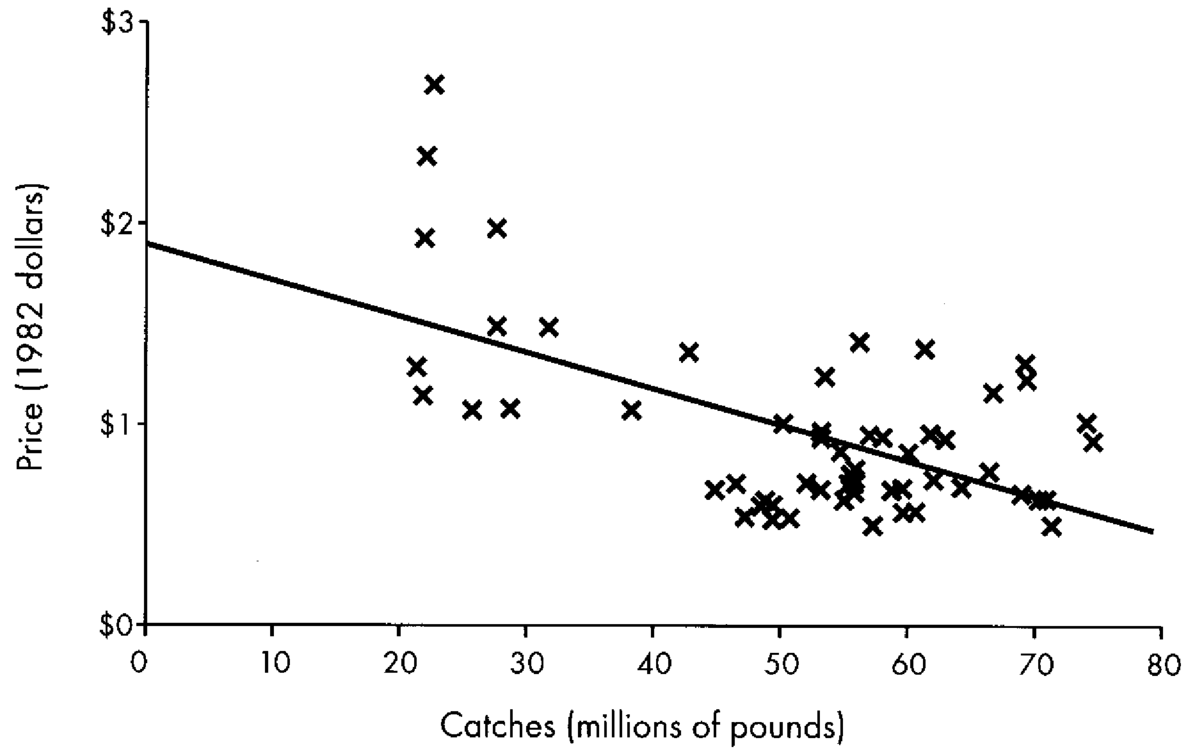


Figure 6. Ex-vessel demand for Pacific halibut.

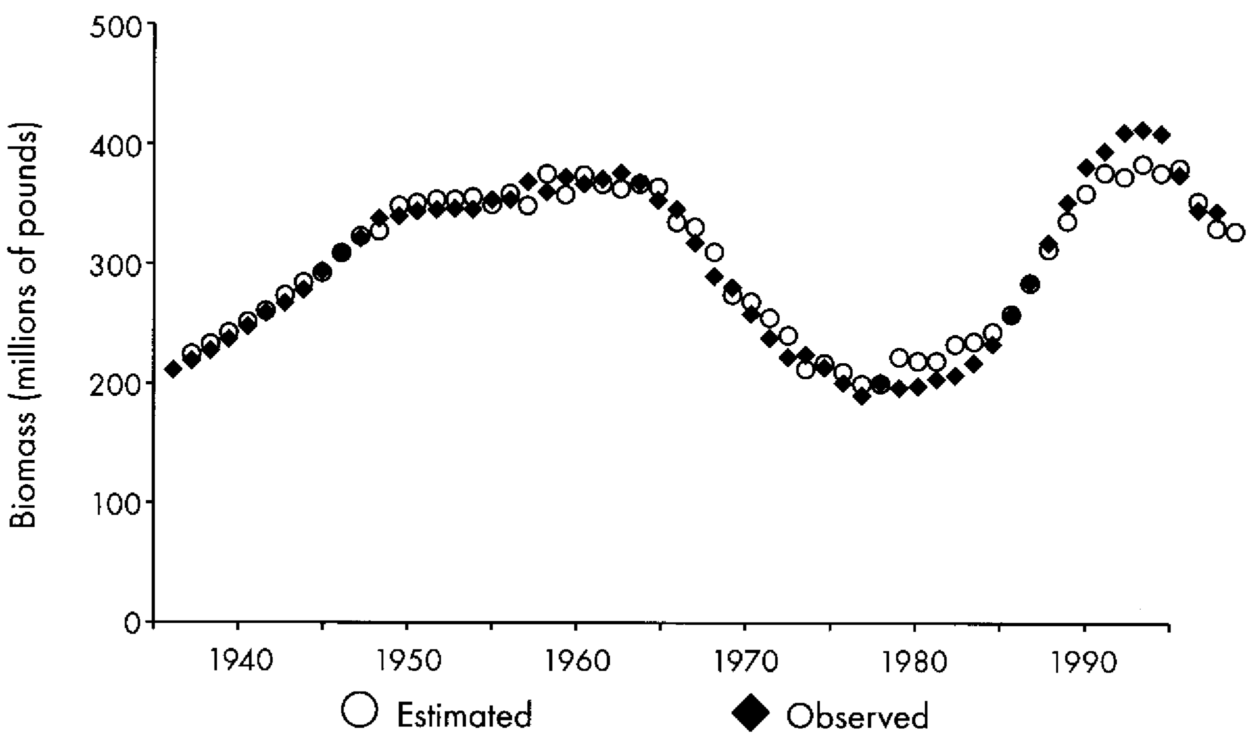


Figure 7. Halibut biomass in the northeast Pacific Ocean: observed and estimated.

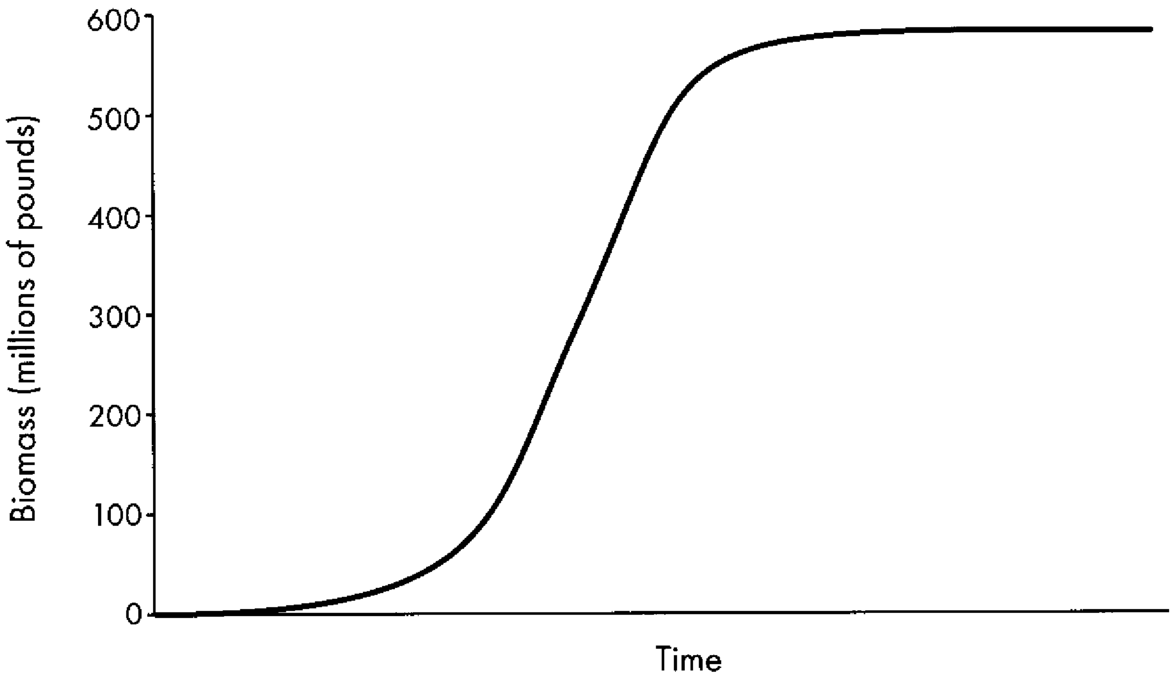


Figure 8. Halibut stock dynamics in the northeast Pacific Ocean.

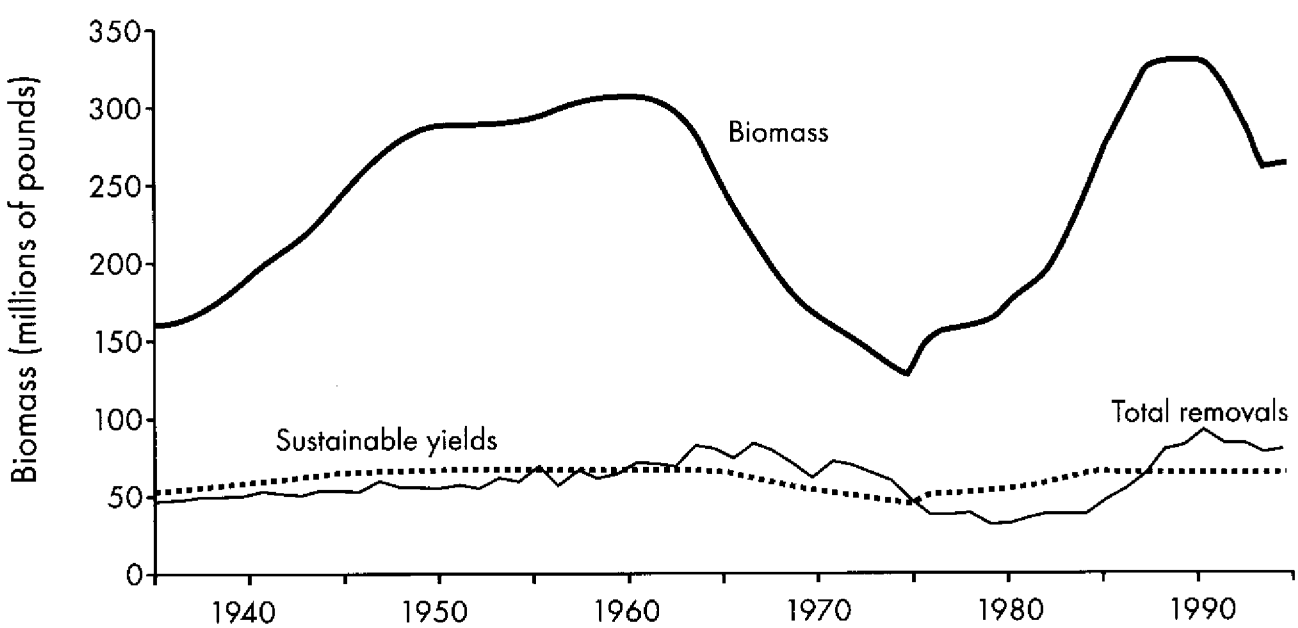


Figure 9. Biomass, removals, and sustainable yields of halibut in the northeast Pacific Ocean.

skates is $77.1 million, while the MSY catch of 67.6 million pounds only generates $47.5 million in revenue. Thus, it is unlikely that fishers would, over the long run, choose to harvest the MSY. However, the short-run cost of fishing 260,000 skates is only $21.4 million (Figure 13a). Therefore, if the fleet consisted of 260,000 or more skates, it can be anticipated that it would, in the short run, harvest the MSY. In the long run, some fishers would exit until the total amount of fishing effort was reduced to 170,000 skates. Since the level of effort used in the fishery during recent years (Figure 5) has been less than that required to harvest the MSY it is unlikely that fishers would harvest up to the full MSY, and in fact, it can be anticipated that the amount of effort in the fishery will continue to decline from present levels.

If the fisheries were managed so as to maximize the net benefits to society, and if fishers behaved as a single entity, the level of effort employed in the harvest of halibut would decline to 50,000 skates (Figure 12a). At the MEY effort level, the long-run total costs would be $14.7 million while revenues would equal $44.9 million for a net profit of $30.2 million.

Figures 12b and 13b focus on differences in harvest levels under the three alternative management approaches. By definition, MSY maximizes catch. In both long-run and short-run time frames, the MEY and open access solutions select harvest levels that are below MSY. Although the harvest levels selected under MEY and open access criteria are sustainable, they do not correspond to the maximum of the sustainable yield curve (Figure 10).

Stocks that are reduced to low levels of biomass may be more vulnerable to collapse than stocks at higher levels of abundance. Figure 10 indicates that most sustainable yields can be achieved at two different levels of biomass. Because biomass is greater for catches associated with the descending arm of the sustainable yield curve, they are more conservative than catches associated with the ascending arm. Figures 12c and 13c focus on the biomass levels maintained by the alternative management policies under short-run and long-run time frames. The long-run MEY solution is the most conservative, maintaining a standing biomass of 498 million pounds. The long-run open access solution is also more conservative than MSY (Table 1)

Table 1. Characteristics of three alternative objectives for the management of halibut in the northeast Pacific Ocean.

	Average	Maximum sustainable yield			Open access			Maximum economic yield		
	1974–92	Low cost	Baseline	High price	Low cost	Baseline	High price	Low cost	Baseline	High price
Effort (million skates)	0.18	0.26	0.26	0.26	0.51	0.17	0.38	0.08	0.05	0.10
Total cost (millions, $U.S.)	$53.9	26.2	77.1	77.1	51.1	49.8	112.3	7.7	14.7	27.8
Catch (million pounds)	42.9	67.6	67.6	67.6	51.7	63.0	62.7	44.8	34.8	49.8
Price (U.S. $)	$1.37	0.70	0.70	0.70	0.99	0.78	0.79	1.11	1.29	1.02
Total revenue (millions, $U.S.)	$53.9	47.5	47.5	115.1	51.1	49.8	112.3	49.8	44.9	100.7
Profit (millions, $U.S.)	$0.0	21.4	–29.5	38.4	0.0	0.0	0.0	42.1	30.2	73.0
Biomass (million pounds)	247.2	293	293	293	151	369	215	464	498	444

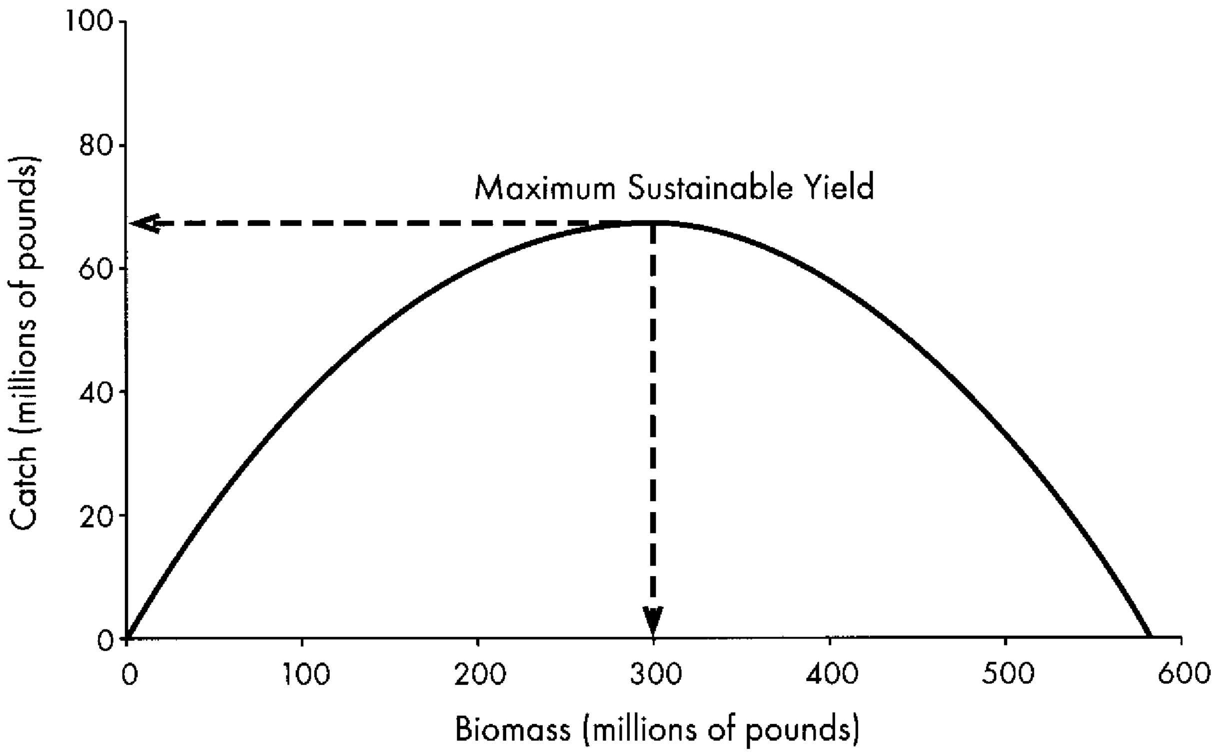


Figure 10. Sustainable yields of halibut in the northeast Pacific Ocean.

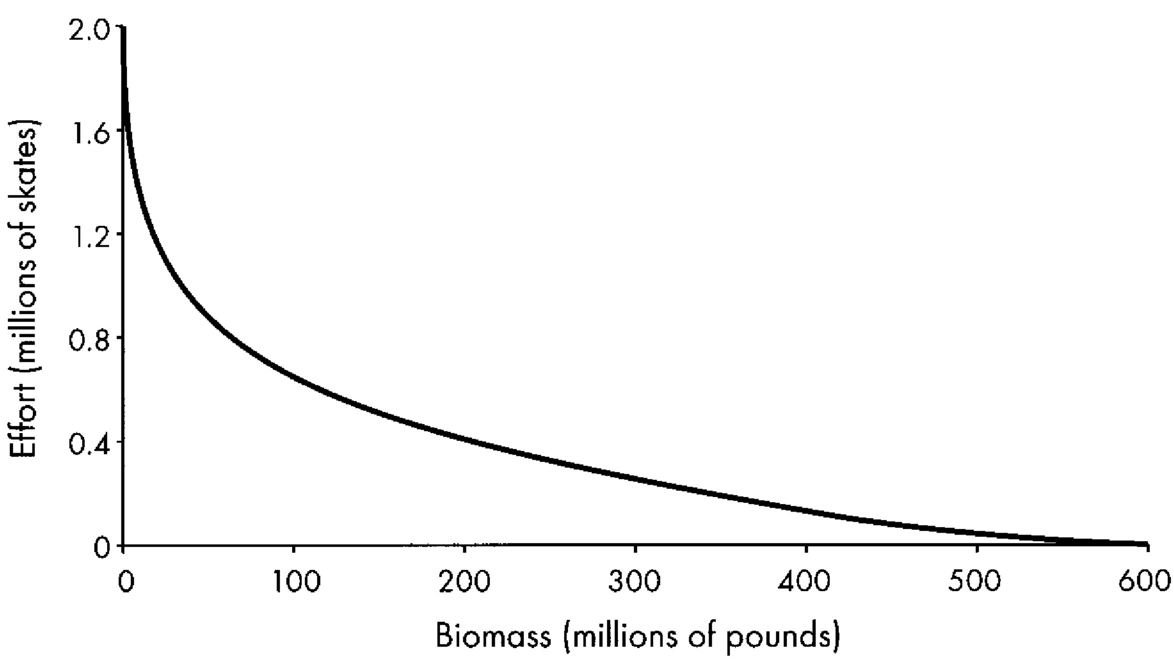


Figure 11. Effort required to catch the sustainable yield as a function of the biomass of halibut in the northeast Pacific Ocean.

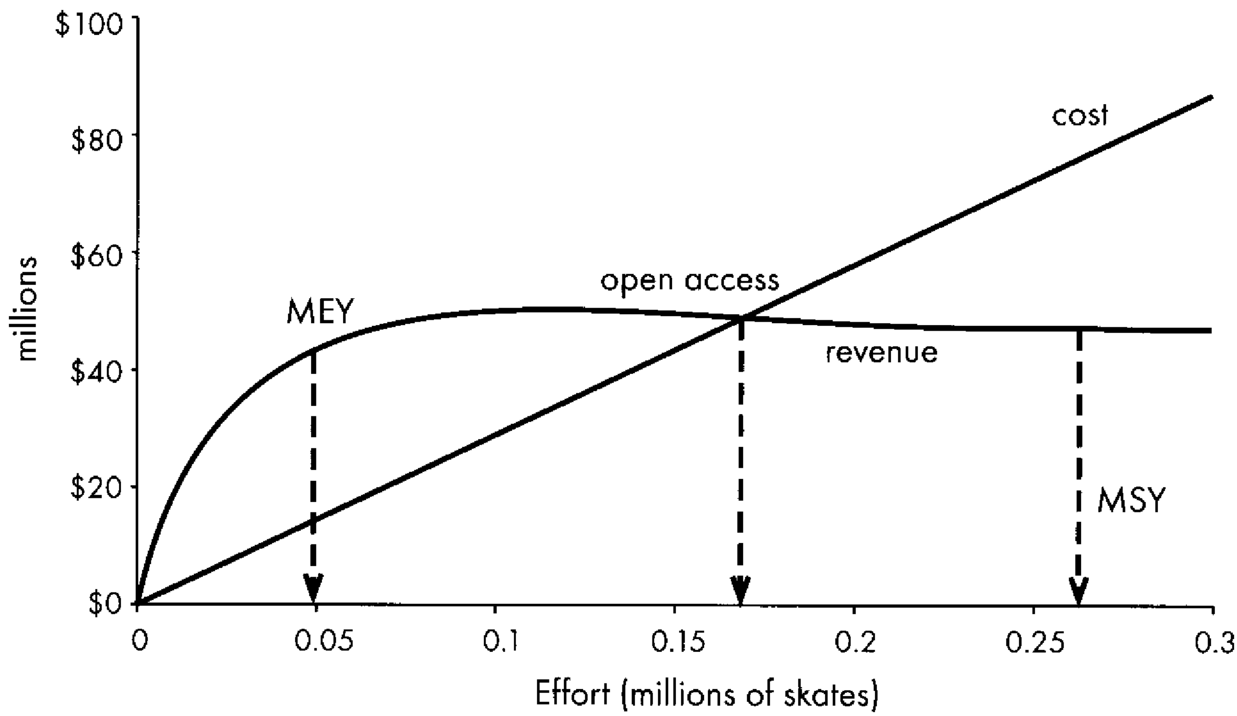


Figure 12a. Revenue, costs, and profit as functions of the effort used to catch halibut.

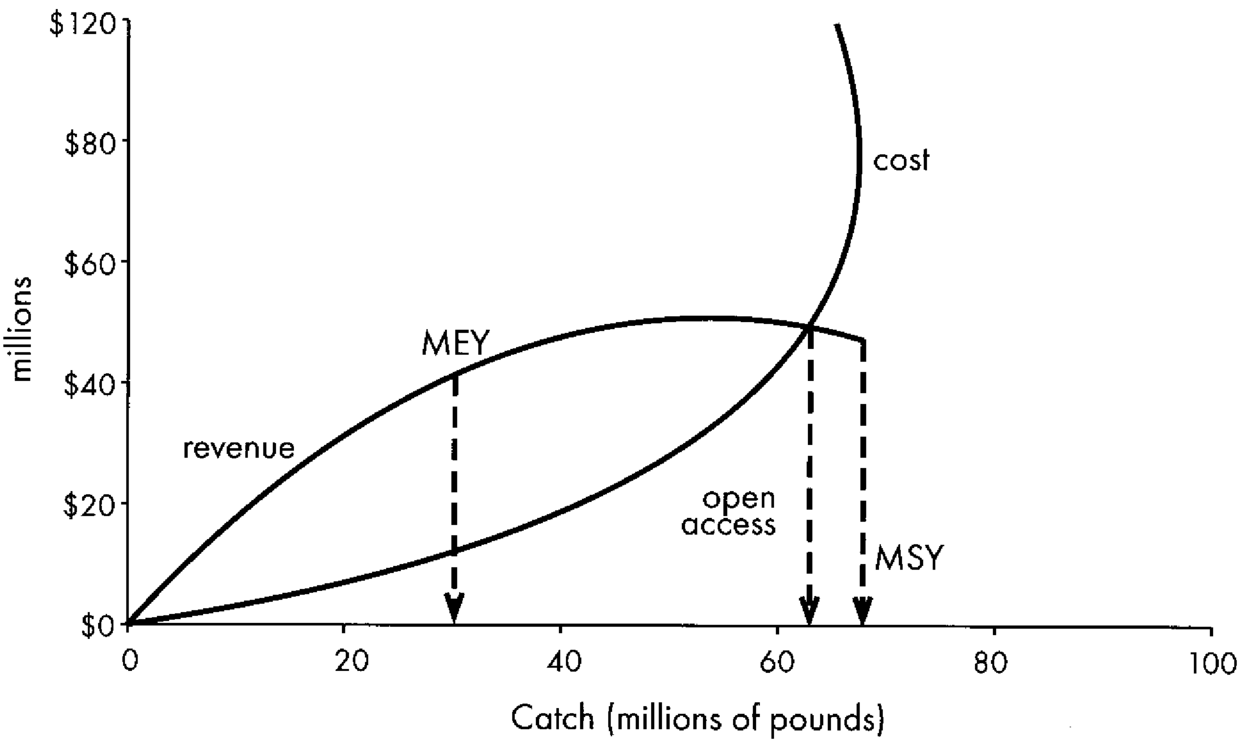


Figure 12b. Revenue, costs, and profit as functions of the sustainable yields of halibut.

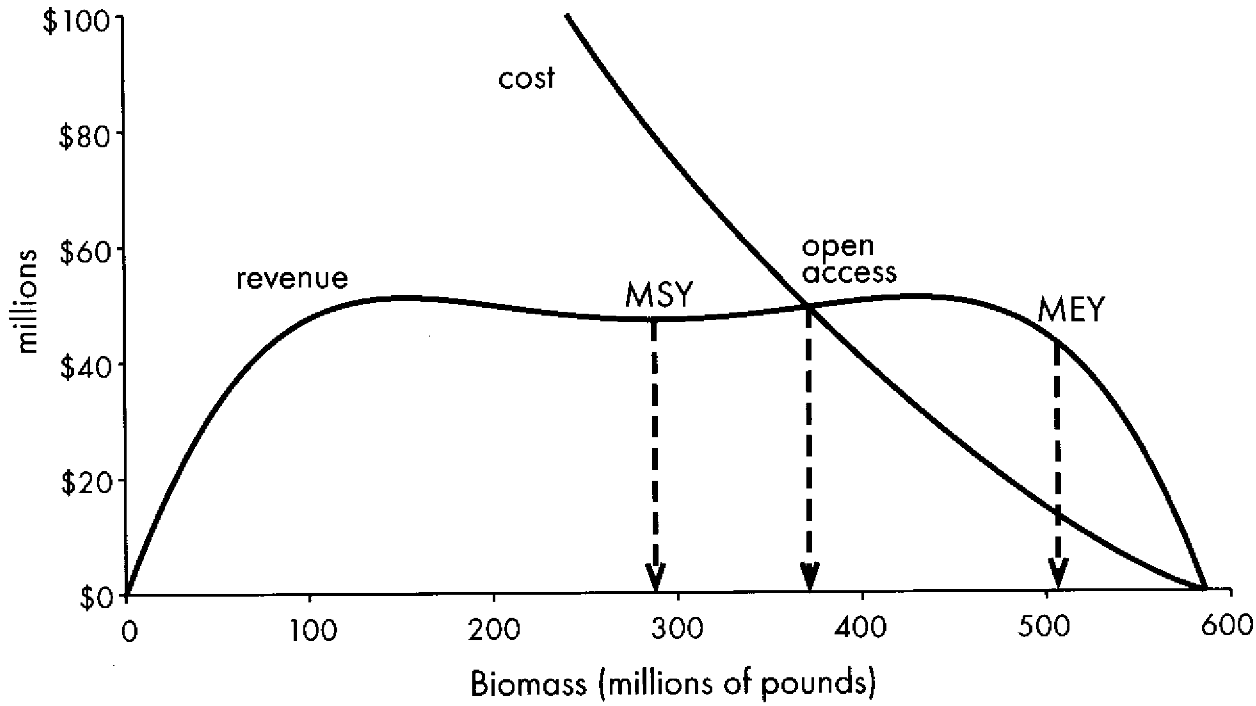


Figure 12c. Revenue, costs, and profits as functions of the biomass of halibut.

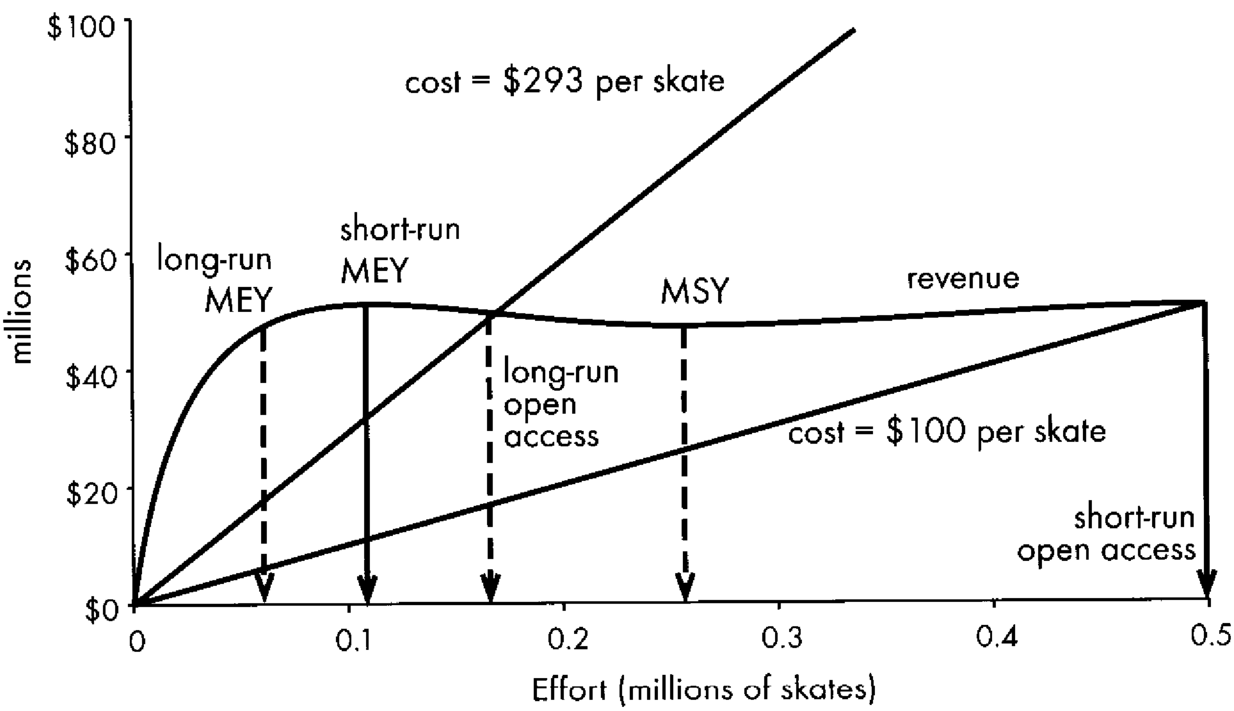


Figure 13a. Long-run and short-run revenue, costs, and profit as functions of the effort used to catch halibut.

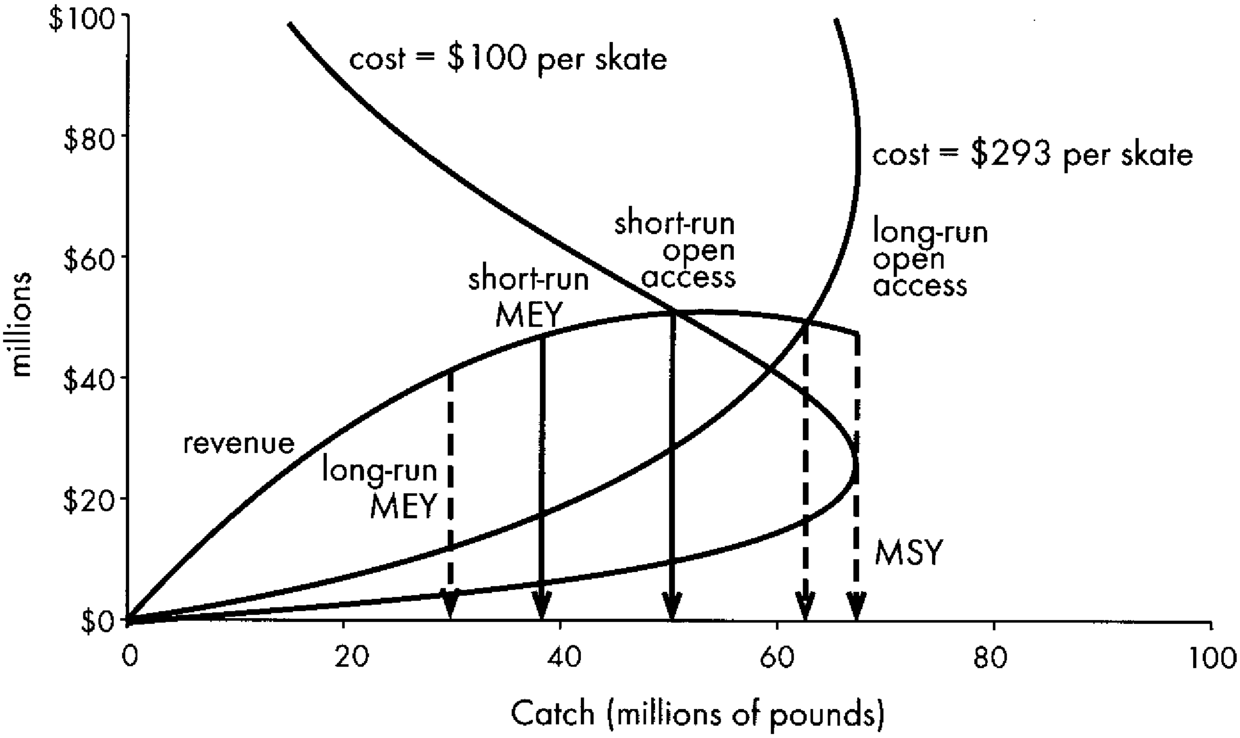


Figure 13b. Long-run and short-run revenue, costs, and profit as functions of the sustainable yields of halibut.

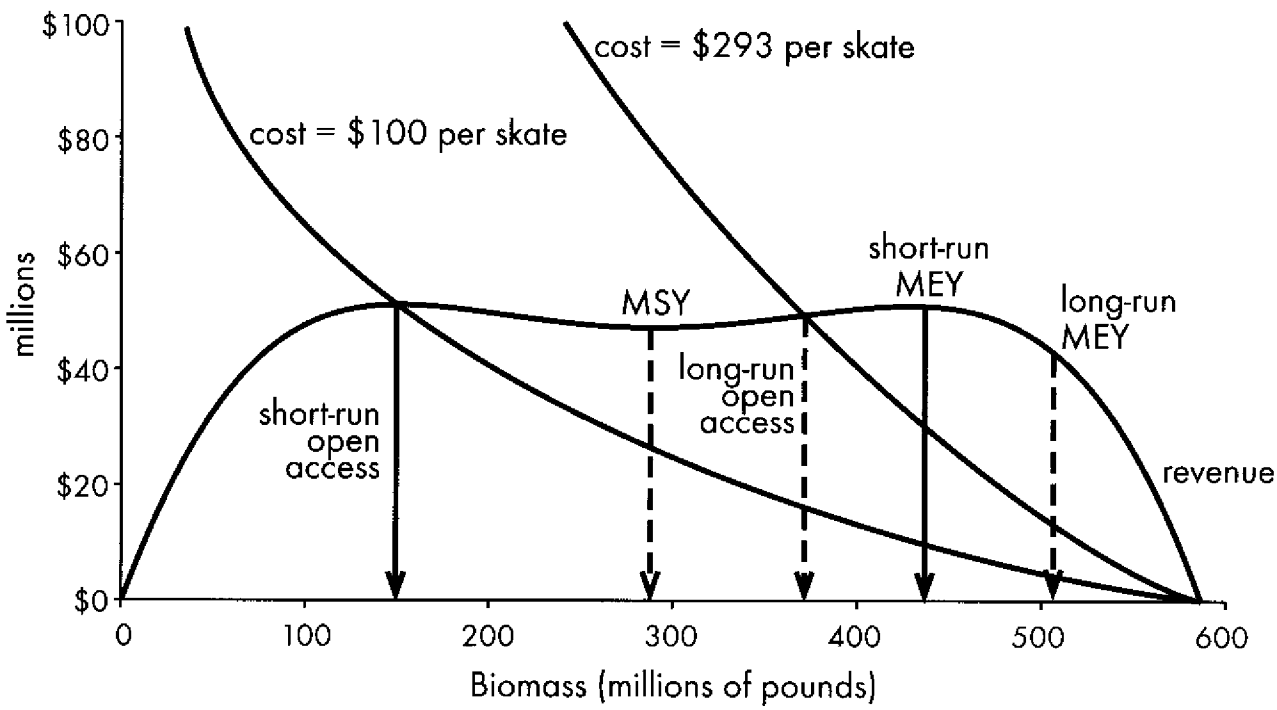


Figure 13c. Long-run and short-run revenue, costs, and profit as functions of the biomass of halibut.

because the long-run costs of harvesting MSY exceed the long-run benefits. However, in the short run, the open access solution reduces biomass below the biomass that produces MSY. The coastwide exploitable biomass of halibut has been below the level that produces MSY in 44 of the last 58 years, including the three most recent years.

Figures 14a–c show the effects of a permanent one dollar per pound increase in the real price of halibut. The increase represents an outward shift in the ex-vessel demand curve (Figure 6). Following the creation of individual quotas in 1990, the prices offered Canadian halibut fishers have risen by $0.50–$1.00 (U.S.) per pound. At these higher prices, the revenue gained under each of the three management strategies increases. Because effort is held constant under the MSY strategy, costs do not increase, so the increased revenue contributes directly to increased profits ($38.4 million). Under the open access strategy, effort expands to exhaust profit, and biomass is reduced to 215 million pounds. Although there is an increase in effort under the MEY criterion, biomass remains above the biomass that supports MSY, thus the economically optimal solution remains more conservative than the MSY solution. At these new higher prices, the MEY solution results in net benefits of $73 million.

CONCLUSION

The actual level of commercial catches of halibut is a public policy choice delegated to the management agency. Why has the IPHC failed to maximize the benefits that could be obtained from this fishery? The answer lies in the forces that operate when fishery resources are allocated under a derby mechanism. Although the magnitude of net benefits from the halibut fishery depends on the choice of harvest level and standing biomass stock, the potential profits can only be realized if the race for fish is halted. The race for fish results from the rule of ownership by capture. The quantity of fish that can be obtained by fishers is determined by their ability to maximize catch per unit of time. What they do not capture today may not be available for them to pursue tomorrow. Once effort has expanded to the point that profits are eliminated, there is no incentive for additional effort to enter.

Consider the response of fishers to a sudden increase in the price offered for fish, holding the TAC constant. Although fishers are capable of landing the TAC without incurring additional costs—thereby reaping the full benefit of increased revenues—the increased price serves only to permit an escalation of the fish race. Fishers unwilling

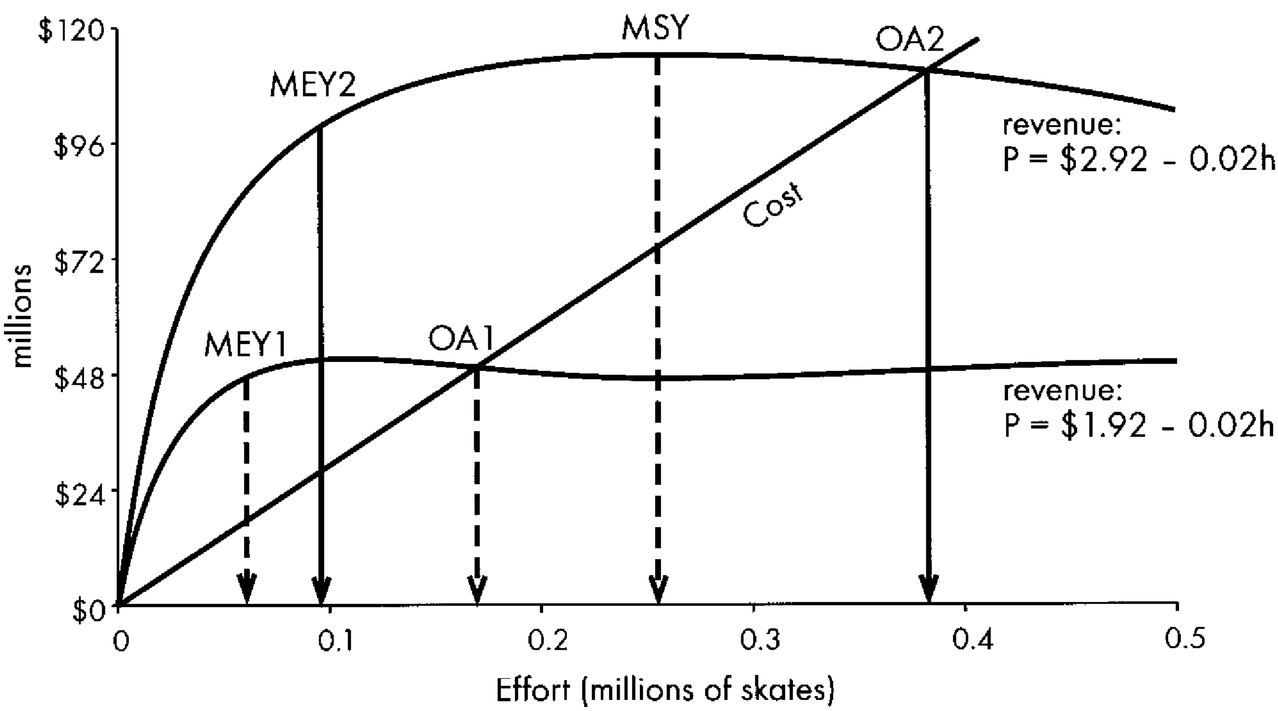


Figure 14a. Revenue, costs, and profit as functions of the effort used to catch halibut.

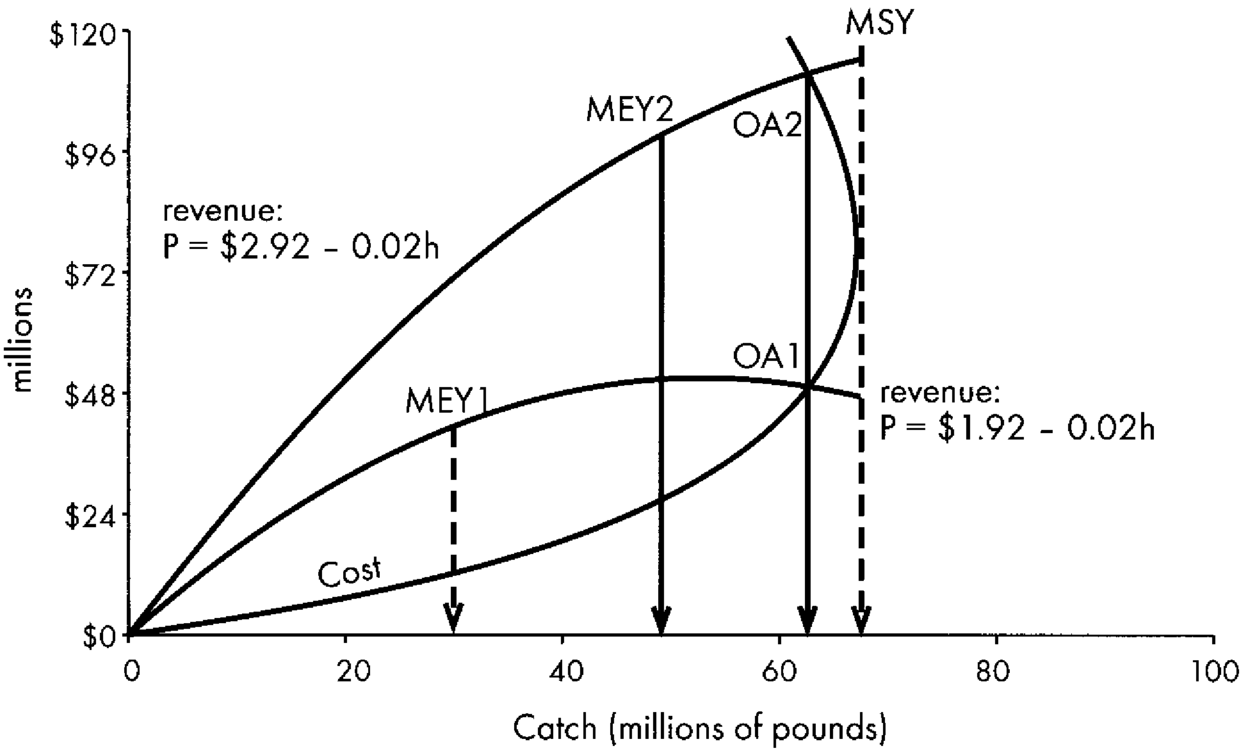


Figure 14b. Revenue, costs, and profit as functions of the sustainable yields of halibut.

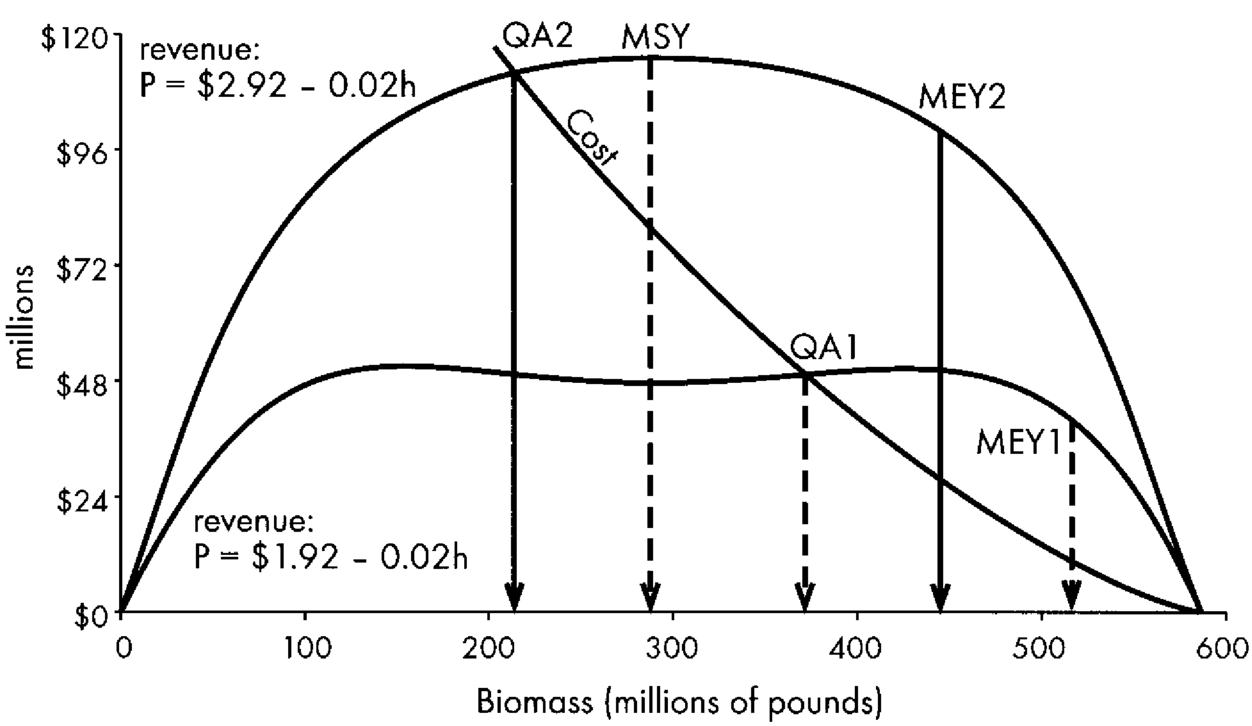


Figure 14c. Revenue, costs, and profit as functions of the biomass of halibut.

to invest their increased earnings in catch enhancing technologies find that their catches diminished, while those who invest enjoy ephemeral increased catches. In the end, there is no change in the number of fish caught; however, the cost of catching the TAC has increased.

If, instead, fishermen are ensured of fixed shares of the TAC, the incentive to race is eliminated. Fishers who are not at risk of losing their share of the resource to others are unlikely to squander their earnings on technologies that increase the cost of catching fish.

REFERENCES

Criddle, K.R. 1993. Optimal control of dynamic multispecies fisheries. In: G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn (Eds.), Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program Report No. 93-02, University of Alaska Fairbanks.

Criddle, K.R. 1991. Modeling dynamic fish populations. U.S. Dept. Commerce, NOAA Technical Memorandum NMFS F/NWC-1309.

Criddle, K.R., and A. Havenner. 1991. An Encompassing approach to modeling fishery dynamics: Modeling dynamic nonlinear systems. Natural Resource Modeling 5:55–90.

Hardin, G. 1968. The tragedy of the commons. Science 162:1243–1248.

International Pacific Halibut Commission. 1992. 1991 Annual Report. IPHC, Seattle, WA.

North Pacific Fishery Management Council. 1991. Revised supplement to the draft supplemental environmental impact statement and regulatory impact review/initial regulatory flexibility analysis to the groundfish fishery management plans for the Gulf of Alaska and the Bering Sea/Aleutian Islands: Longline and pot gear sablefish management in the Gulf of Alaska and the Bering Sea/Aleutian Islands. NPFMC, Anchorage, AK.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bull. Inter-Amer. Tropical Tuna Comm. 1:27–56.

DISCUSSION

(**José Stuardo**, *Universidad de Concepción.*)

During the last year there has been a lot of criticism of conventional economics and particularly resource economics. We probably all have read the generalizations. There exists now a new view of economics called ecological economics. Please comment on the principles and objectives of ecological economics as opposed to traditional or conventional economics.

Criddle. The field of ecological economics is quite recent and it's not one in which I have a large amount of training; but I see its roots as having been present in the initial considerations of resource economics and certainly in their extension into environmental economics. They've got common roots in trying to measure the value of alternative uses of resources. This is not an easy process. With a commercial operation, it can be fairly simple to get a measure of what the costs are of harvesting, and what the revenues are that are generated from the harvesting, and come up with a measure of value. If you move to the next level of complexity and try to value a sport-fishery activity, it becomes more difficult. You can get a measure of what costs people incurred to participate in that fishery, but it's very hard to come up with a measure of the value they obtained from their participation, although methods have been developed for trying to get at that.

My understanding of ecological economics is that it's seeking again to push at getting a measure of the value of maintaining environmental amenities and maintaining stocks of various species. I think the driving force on this is that people would like to have a unifying unit of measurement. A constant unit of measurement—a measurement of value that could be constant across all different types of uses—would allow choices among uses to ensure that the resource went to the combination of uses that resulted in the highest amount of benefit. I'm very sympathetic with that goal. However, I recognize that there can be considerable difficulty obtaining a consistent unit of measurement for the value of some of these uses, such as preservation of stocks. I think we're also going to have to accept that not all decisions can be based strictly on economic rationalization. Economics can contribute some understanding of where sources of value are, but many decisions still have to be made in the public arena where it is possible to balance equities and other concerns that cannot be directly addressed with profit maximization as a goal. Economics provides some description of the workings of the economic system, much like biology contributes to a description of the operations of an ecosystem, but neither defines the goals that should be sought for that resource.

Problems of Radioactive Waste Dumped in the Seas Surrounding Russian Territory

Yury E. Kazakov
Ministry of Protection of the Environment and Natural Resources
Moscow, Russia

Recently, the international public has been actively discussing the problem of dumping radioactive waste in the seas, often using unverified information, which impedes the objective analysis of the situation. This paper presents a brief summary and analysis of data collected by the governmental commission established by the Presidential Decree of October 24, 1992, to examine the problem of radioactive dumping.

The commission included representatives of the Russian Ministry of Environmental Protection and Natural Resources, the Ministry of Defence, the Ministry of Foreign Affairs, the Ministry of Health, the State Committee for Nuclear Power Inspection, and other ministries and departments. The commission was chaired by Professor A.V. Yablokov, Advisor to the President of the Russian Federation on the Environment and Public Health. The report contained a wide range of facts—including many never published before and previously considered confidential—obtained by working groups established under the framework of the commission to examine the following problems:

- The international aspects of dumping radioactive waste in the seas
- Dumping radioactive waste in Russian Federation territorial seas
- Radiological conditions in areas where radioactive waste has been dumped in the Russian North and Far East
- Ways to solve the problem of radioactive waste management involving the Navy and civilian navigation structures

The Report of the Commission, often referred to as the "White Book" or the "Yablokov Report," was submitted to the Russian President, approved, and made open to the public in view of developing governmental programs and governmental decisions on measures to prevent further unauthorized radioactive waste dumping in the seas and to manage radioactive waste and exhausted nuclear materials—their utilization and disposal—for the period up to the year 2005. The complete text of the report is available to the international community (Russian President Administration, 1993).

HISTORICAL AND INTERNATIONAL ASPECTS OF RADIOACTIVE WASTE DUMPING IN THE SEAS

Numerous countries with nuclear-powered ships and nuclear industry have regularly dumped liquid and solid radioactive wastes. The international community is increasingly concerned about the accumulation of such waste, as well as accidents in nuclear-powered ships and submarines. Serious questions have also been raised about the nuclear waste disposal practices of the former Soviet Union (and, more recently, Russia).

Major areas of solid radioactive waste dumping in the World Ocean are shown in Figure 1 (Gromov et al., 1985). In 1946, the United States became the first country to dispose of radioactive wastes in the seas (in the northeastern Pacific, 80 km off the California coast).

Marine dumping of low-activity solid radioactive waste was started almost simultaneously with the wide development of the nuclear power industry. Great Britain started dumping in 1949, Japan in 1955, the Netherlands in 1965. Up to the year 1983, 11 countries practiced solid radioactive dumping in the open sea (see Table 1).

International Atomic Energy Agency (IAEA) data show that the total activity of radioactive wastes dumped in the World Ocean during 1946–1982 makes up about 1.24 MCi (46 PBq), with no account either for disposal by the USSR and Russia—which so far has never been reported to either the IAEA or any other international organizations—or of liquid radioactive waste dumped for

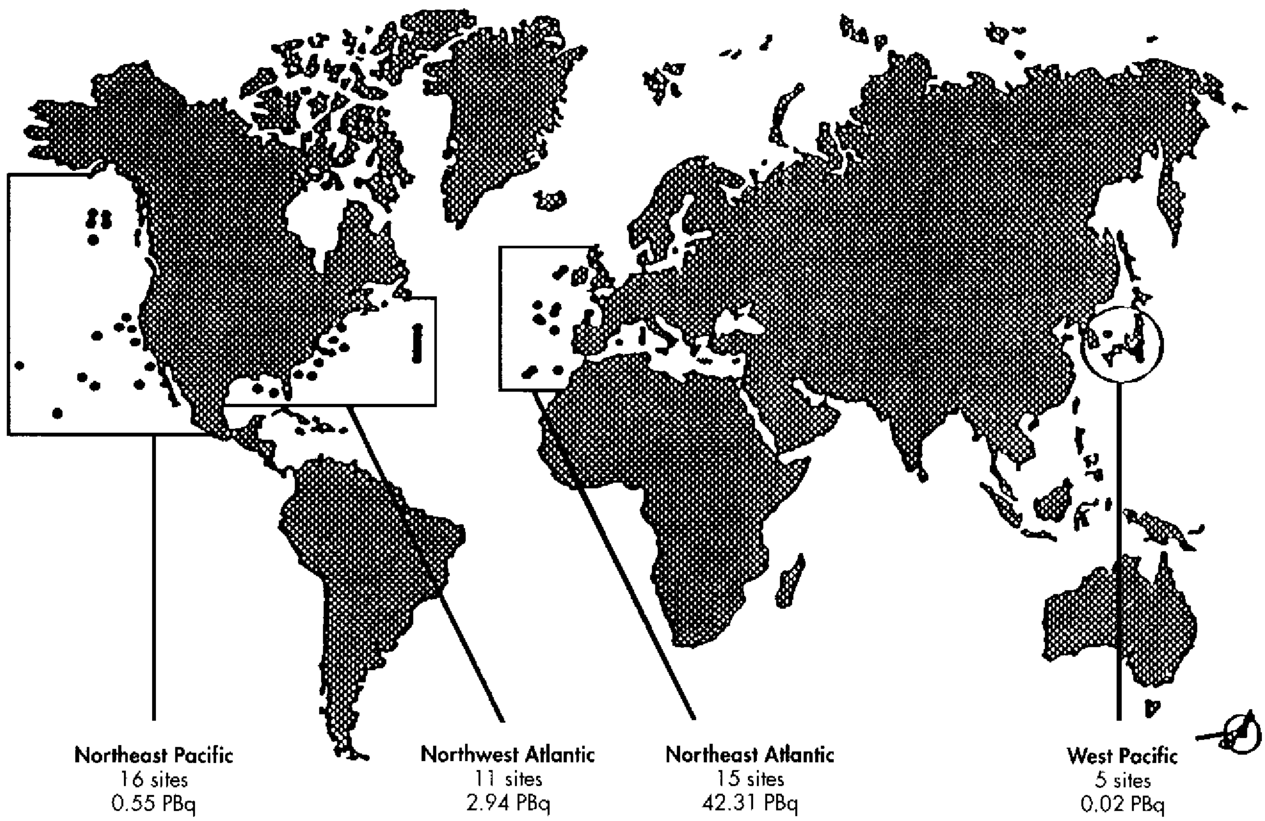


Figure 1. Areas used by countries other than the Soviet Union for radioactive waste dumping (Gromov et al., 1985).

nuclear fuel processing plants (including 915.4 KCi [0.57 PBq] in the Pacific Ocean and 1,222.4 KCi [45.2 PBq] in the Atlantic Ocean).

The highest amount of radioactive waste (excluding the USSR) was dumped in the World Ocean by the United States (6.5%), Switzerland (9.6%), and Great Britain (77%). It should be noted that Great Britain made wide use of disposing liquid radioactive wastes from nuclear power enterprises by dumping them into the Irish Sea through pipelines. The scale of this dumping was large enough (on the order of 1 MCi), to be traced as far as the Barents and Kara seas.

Growing worldwide concern over marine contamination by radioactive waste has led most countries to support a prohibition against dumping any kind of radioactive waste in the sea. This is the aim of the Danish initiative which envisions complete banning of radioactive waste dumping in the sea, and the idea behind a moratorium on radioactive waste marine dumping first put forward in 1983 in the framework of the London Convention. The resolution adopted then calls for all the countries to refrain from marine dumping of all kinds of radioactive waste until the end of the Intergovernmental Panel on Solid Radioactive Wastes Dumping (IGPAD) terms of reference. Later on, the moratorium was extended until 1993 based on the assumption that by that time the IGPAD should complete the assessment and propose recommendations on dumping medium- and low-activity radioactive waste in the sea.

The United States, France, Great Britain, and Japan do not reject the moratorium itself, but insist on a transition period to have time to settle all problems concerning radioactive waste management, utilization, storage, and disposal on land.

The United Nations Conference on Environment and Development supported an initiative of Denmark, Iceland, and Norway by adopting a recommendation prohibiting marine dumping of radioactive waste. This recommendation (A/Conf.

Table 1. Characteristics of radioactive waste dumped in the World Ocean by various countries (excluding data on the USSR and Russia*). IAEA TECDOC–588, 1991.

Atlantic Ocean

Country	Amount dumped	Percent	Years
Belgium	2,120.00	4.63	1960–1982
Great Britain	3,5077.00	76.55	1949–1982
Germany	0.20	0.0004	1967?
Italy	0.19	0.0004	?
Netherlands	336.10	0.73	1967–1982
United States	2,942.00	6.42	1949–1967
France	353.40	0.77	1967–1969
Switzerland	4,419.00	9.64	1969–1982
Sweden	3.23	0.01	1963
Total:	4,552.50	98.76	

Pacific Ocean

Country	Amount dumped	Percent	Years
Korea	No data		?
New Zealand	1.04	0.002	?
United States	554.20	1.21	1946–1970
Japan	15.44	0.03	1955–1969
Total:	570.70	1.24	

* No account taken of effluents from nuclear fuel processing plants, lost nuclear ammunition, and other sources of ionizing radiation, submerged nuclear submarines, and radionuclides occurring in the ocean as a result of underwater nuclear explosions.

151/26, 1992), approved by about 150 countries (including Russia), evidently reflects the positions of many countries. In general, the issues of marine dumping of radioactive waste are regulated in international law by the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters signed in London in 1972 and entered in force August 30, 1975 (for the former Soviet Union, since January 1976). The Convention is effective in all marine areas except internal marine waters.

The London Convention prohibits dumping waste with a high level of radiation. Dumping low- and medium-radiation waste is allowed by special permission with the notification of the International Marine Organization Secretariat, provided that a representative of a relevant international organization is present on board the vessel performing dumping operations and the three major requirements of the IAEA are met (IAEA Safety Series, 1990): location of dumping areas outside the continental shelf, internal and outlying seas; a depth of no less than 4,000 meters in the areas of dumping; only within the areas between latitudes 50°N and 50°S.

The only areas near Russia that comply with the above requirements are in the Far Eastern seas of the Russian Federation.

Regional multilateral agreements related to the problems of marine dumping of radioactive waste include the Convention on the Protection of the Marine Environment of the Baltic Sea (Helsinki, 1992), the Convention on the Protection of the Marine Environment of the Northeastern

Atlantic (Paris, 1992), and the Convention on the Protection of the Black Sea from Pollution (Bucharest, 1992), signed by all the Black Sea countries (including Russia), which unconditionally prohibited the dumping of radioactive matter in this basin.

RADIOACTIVE WASTE DUMPING IN SEAS WASHING THE RUSSIAN FEDERATION

The nuclear arms race and the development of a nuclear power industry have generated a large amount of radioactive waste. The problem of managing this waste was given little attention until recently. This resulted in a significant pollution of the environment. Construction and operation of icebreakers equipped with nuclear power units and nuclear submarines also led to the generation of substantial quantities of radioactive waste.

During the Cold War, the problem was never considered a priority, and the simplest decision was to dump radioactive waste directly into the sea, a strategy widely used by the majority of countries with a developed nuclear power industry.

After the London Convention came into force, the USSR took a number of steps to comply with international standards and commitments. In 1979, the USSR Council of Ministers issued Decree No. 222 "On measures to comply to the commitments of the Soviet side under the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter."

When radioactive waste dumping from civilian ships was phased out, no measures were taken to stop dumping radioactive waste from Navy facilities, which may be attributed to the overall inefficiency of radioactive waste management in the country, lack of technical facilities for radioactive waste processing in the Navy, insufficient coastal storage capacity, and inadequate interpretation of the USSR Ministry of Foreign Affairs' concept of "warship immunity," which did not consider radioactive waste dumping from Navy ships a violation of London Convention requirements.

During 1959–1976, before the London Convention entered into force in the USSR, a large portion of radioactive waste was dumped in the sea. Even after the enforcement of the Convention, its requirements were deliberately and frequently ignored.

The rules of marine dumping of radioactive waste then in force in the USSR took no notice of either the obligatory selection of dumping areas outside the continental shelf, internal and outlying seas, or the prohibition against dumping radioactive wastes in latitudes above 50°N. The USSR never submitted regular reports on marine dumping of radioactive wastes to the International Marine Organization or the IAEA, as is required under the London Convention. Moreover, in 1989, the answer to the London Convention questionnaire read, "the USSR has never dumped, is not dumping and does not plan to dump radioactive wastes into the seas" (IAEA TECDOC–588, 1990).

After Russia took over the USSR's commitments under international agreements, the London Convention became genuinely fully effective for Russia. Marine dumping of radioactive wastes is now regulated by common international standards.

Since the Navy's rules of marine dumping of radioactive wastes in the North, and to some extent in the Far East, strongly contradict the London Convention, the earlier ministerial instructions and regulations are no longer acceptable for Russia. Article 50 of the Law of the Russian Federation on Environmental Protection (December 1991) reads, in part: "50.3 Import of radioactive wastes and materials from other countries for the purpose of storage and disposal, submersion, disposal of radioactive wastes and materials in the space is prohibited." Thus the law forbids both radioactive waste dumping in Russian territorial waters and any disposal in any seas of all types of radioactive wastes generated in Russia.

The first radioactive waste dumpings in the USSR were related to the sea trials of nuclear submarines and the nuclear icebreaker *Lenin*. In 1959, 600 m^3 of low-activity wastes (about 20 MCi) were dumped in the White Sea and in 1989, 100 m^3 of liquid radioactive wastes from the nuclear icebreaker *Lenin* (total activity 200 MCi) were dumped near Gogland Island, Gulf of Finland. Radioactive waste dumping in the Northern and Far Eastern seas has been practiced regularly—liquid since 1960 and solid since 1964.

The geographic location of five officially designated areas for liquid radioactive waste dumping in the Northern seas is presented in Figure 2. These areas were selected by Northern Navy headquarters and approved by the general Navy headquarters.

A small amount of dumping was performed outside the designated areas. Figure 3 illustrates the dynamics of liquid radioactive waste dumping into the Northern seas.

According to available information, the total activity of liquid radioactive waste amounts to 24

KCi (903 TBq), and is distributed as follows: Baltic Sea, about 0.2 Ci (0.007 TBq); White Sea, 100 Ci (3.7 TBq); Barents Sea, 12,153 Ci (450 TBq); and the Kara Sea, 8,500 Ci (351 TBq). This does not account for the activity of liquid radioactive waste that entered the seas as a result of leakage from coastal storage and nuclear submarine accidents.

The Murmansk Marine Shipping Company stopped liquid radioactive waste dumping in 1984, whereas the Navy continues these activities, though on a lesser scale.

Solid Radioactive Waste Dumping

Figure 2 also shows the location of officially designated areas where solid radioactive waste could be dumped in the Northern seas. None of these areas meet any of the international requirements for such activities, in terms of depth, distance from the shore, and location of the radioactive waste territories on the globe.

Most of the solid radioactive waste dumped in the Northern seas is low- and medium-activity waste generated by above- and underwater Navy ships equipped with nuclear power units and nuclear icebreakers, as well as ship repairing and shipbuilding plants.

According to available data, the total activity of dumped low- and medium-activity solid radioactive wastes included over 15.5 KCi (574 TBq) in the Kara Sea and about 40 Ci (1.5 TBq) in the Barents Sea.

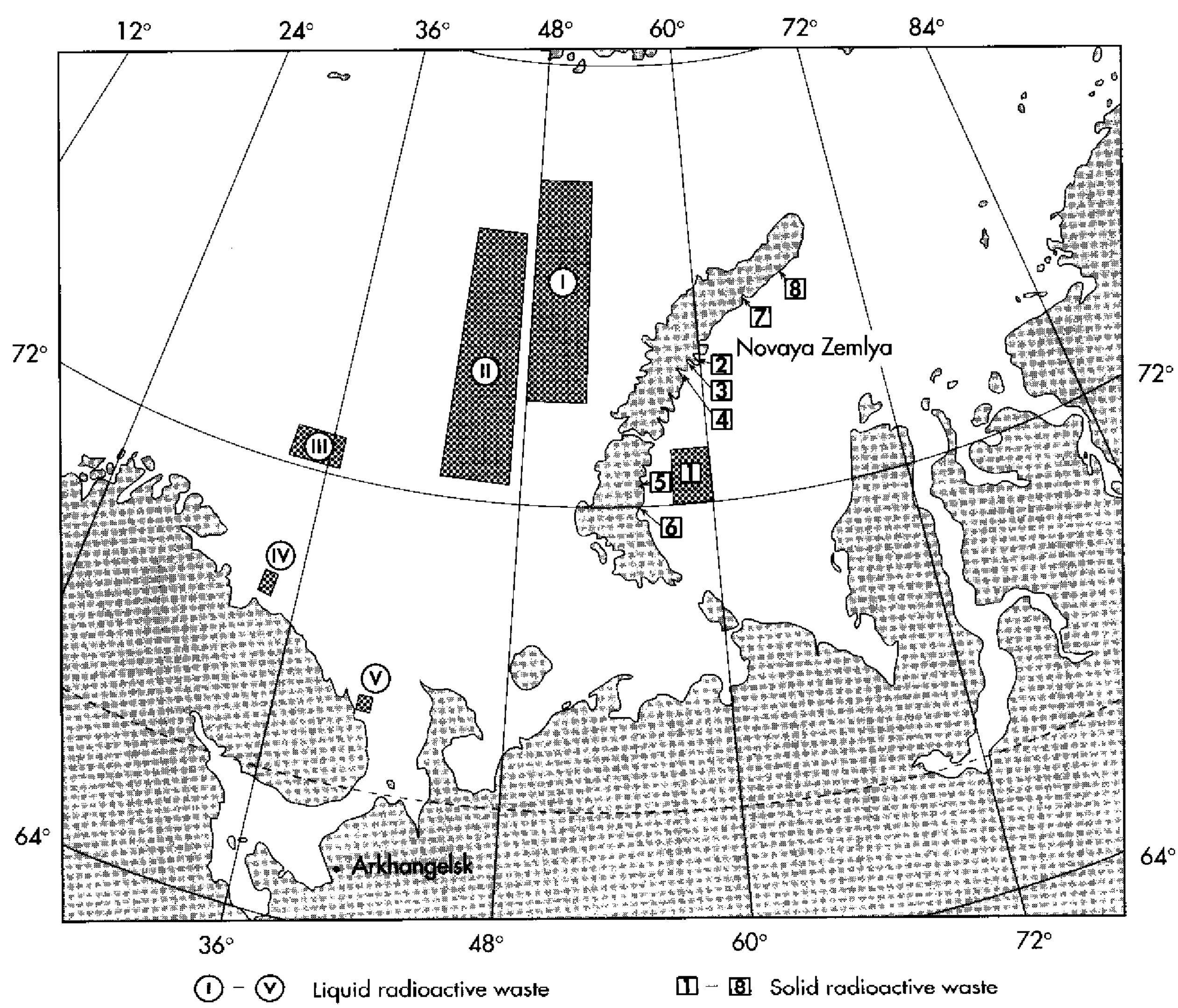


Figure 2. Locations of officially designated dump sites for solid radioactive waste.

In terms of amount, the greatest number of solid radioactive waste dumpings occurred in 1967 and 1982, and dumping activity was the highest in 1983 and 1988 (see Figure 3).

Radioactive Waste Dumping in the Northern Seas

Among radioactive waste dumpings in the Northern seas, the greatest environmental hazard is associated with submerged objects containing exhausted nuclear fuel, which consists of the mixture of fission products and activation products.

According to the Yablokov Report, the following objects are submerged near the Novaya Zemlya coast in the Novaya Zemlya depression: one submarine with two loaded reactors, a reactor compartment with two enriched-nuclear-fuel-containing reactors, a reactor compartment with one loaded and one unloaded reactor, and a nuclear submarine loaded reactor. Prior to dumping, reactor compartments with loaded enriched nuclear fuel were filled with a furfurol-based hardening mixture (except for one nuclear submarine reactor). According to nuclear-power unit designers, such a procedure will prevent enriched nuclear fuel contact with seawater for several hundred years. The screen assembly with enriched nuclear fuel from the icebreaker *Lenin* is additionally encased in a reinforced concrete container and a metal jacket.

Complex scientific studies are required to accurately evaluate the total activity and radionuclide composition of these disposal sites—a necessary condition for assessing the environmental consequences of each dumping activity. These estimations are only possible after analyzing the data on the regime of each reactor for the whole period of its operation. Such an analysis was performed only for the nuclear icebreaker *Lenin*, which allowed estimation of enriched nuclear fuel activity for the time of reactor dumping in 1967 as 100 KCi. As to the reactors dumped near the Novaya Zemlya, no similar analyses were made, and the lower estimate of their activity presented by the Navy is not sufficiently substantiated and requires additional calculations, taking into account the regime of reactor operation. The highest total activity at the time of dumping may amount to no more than 2.3 MCi.

It should be noted that the total activity of the reactor compartment of the nuclear submarine *Komsomolets*, which submerged after an accident in 1989 at the border between the Norwegian and Barents seas on 1,700 m depth and 300 km from the coast, was around 150 KCi. In addition, there is general evidence for ten unloaded reactors being dumped in the bays of Novaya Zemlya and the Kara Sea.

It is difficult to evaluate the total activity of the unloaded reactors. Most of the radionuclides in these reactors were generated by neutron fluxes while the reactor was operating; therefore their activity is greatly dependent on the regime of reactor operation. Besides, the activity of these objects

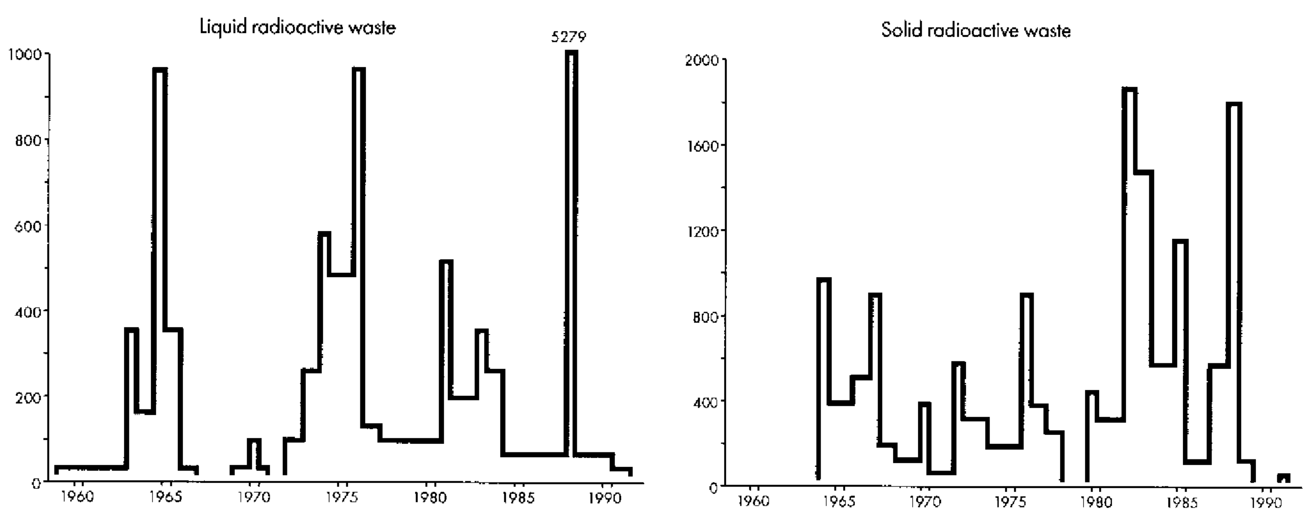


Figure 3. Dynamics of radioactive waste dumping in Northern seas in different years.

depends on their elemental composition. For instance, structural elements of the reactor on the nuclear icebreaker *Lenin* included cobalt, which led to a very high level of induced activity of cobalt 60 (about 50 KCi). The total induced activity for the time of dumping is at least 100 KCi.

Available data show that radioactive waste dumping and disposal in the Barents and Kara seas have been carried out since 1960. The dumping mostly concerns liquid and solid radioactive wastes generated by the operation of nuclear icebreakers and Navy ships (mostly low-, medium- and high-activity solid radioactive wastes, including reactor compartments of nuclear submarines with loaded fuel).

Analysis of radioactive contamination in Northern seas will be incomplete without due regard for possible deposition of manmade radioactive matter from the atmosphere, river runoff, probable input to the Gulf Stream, and the contribution of under- and near-water explosions at the Novaya Zemlya test site.

Table 2 presents the master radionuclide inventory of the Barents and Kara seas ecosystems. In spite of the uncertainty of its estimation, one can assume that the order of magnitude shows the objective situation occurred at the time of radioactive waste dumping.

Liquid Radioactive Waste Dumping

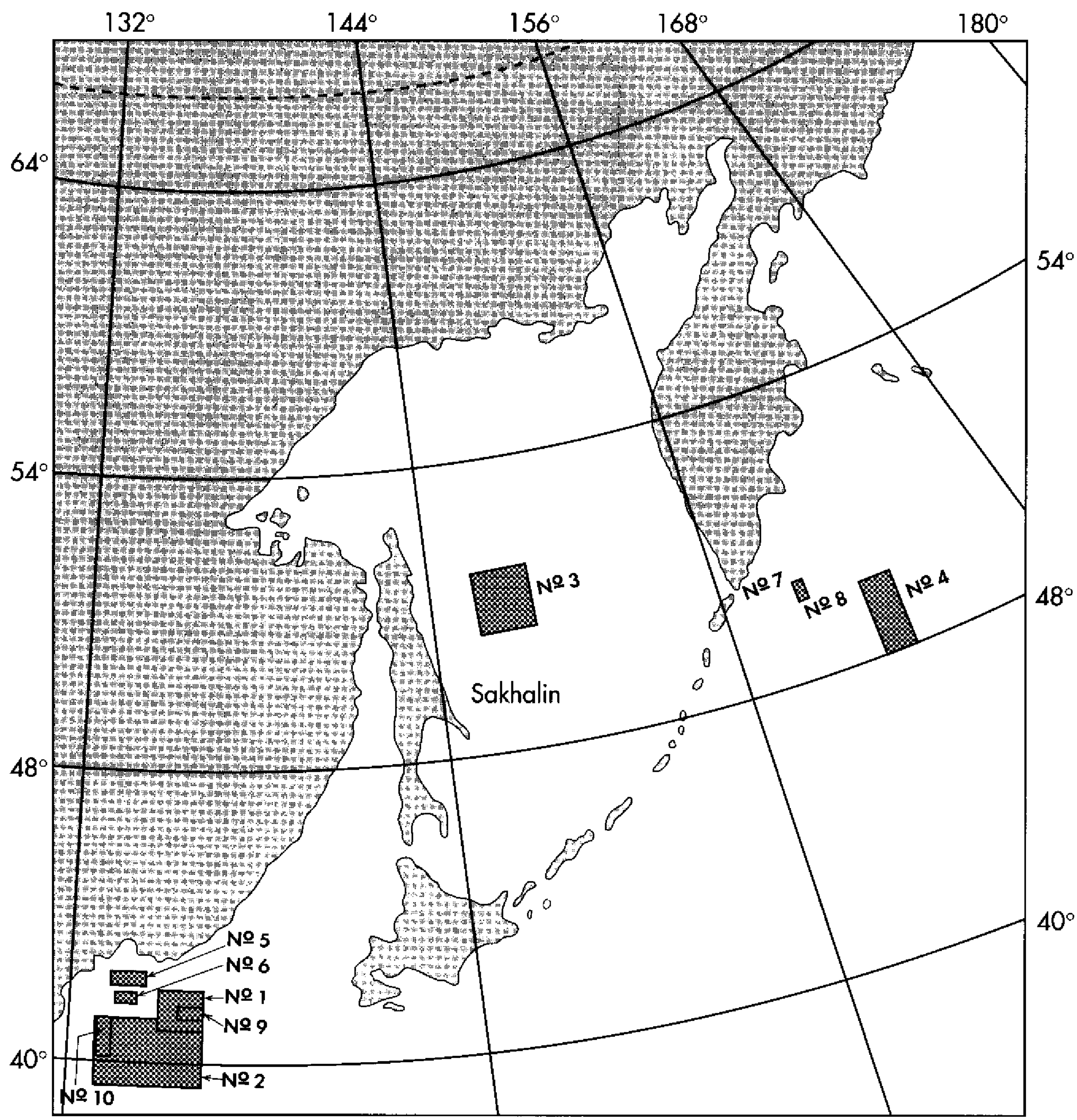
Let us now consider similar data on the dumping and disposal of low- and medium-activity liquid radioactive wastes in the Far Eastern seas of Russia. The geographic locations of designated areas for liquid and solid radioactive waste dumping is shown in Figure 4. Of the ten dumping areas only Site No. 4 meets the IAEA requirements for radioactive waste dumping in terms of depth and location. Liquid radioactive wastes were dumped in the USSR Far Eastern seas between 1966 and 1991. The greatest amount of liquid radioactive waste was dumped at Site No. 7 (near the southeastern coast of Kamchatka Peninsula) and the highest activity of radioactive waste is noted at Site No. 9 (Sea of Japan).

Figure 5 illustrates the yearly dynamics of liquid radioactive waste dumping in the Far Eastern

Table 2. Balance of manmade radionuclides in the ecosystem of the Barents and Kara seas during 1961–1991.

Source of long-lived radionuclides	Barents Sea activity		Kara Sea activity		Total ecosystem activity and contribution		
	KCi	TBq	KCi	TBq	KCi	TBq	%
Atmospheric deposition	100	3,700	70	2,600	170	6,300	6.2
River	6.0	200	33.0	1,200	39	1,400	1.4
Input through Gulf	200	7,400	—	—	200	7,400	7.3
Solid and liquid radioactive waste dumping							
Solid radioactive waste dumping with enriched nuclear fuel	—	—	2,300*	85,300*	2,300*	85,130*	84.4
Under- and above-water nuclear explosions			No data				
Total (upper limit)	319	11,780	2,419	89,700	2,739	101,300	100

* Expert estimate of upper limit activity for the time of dumping.



1–5,7 Liquid radioactive waste; 8 Solid radioactive waste; 6,9,10 Liquid and solid radioactive waste

Figure 4. Locations of designated liquid and solid radioactive waste disposal sites.

seas. In terms of activity, the highest amount of liquid radioactive waste was disposed in 1986–1987. The data available show that the total activity of the liquid radioactive waste dumped in the Far Eastern seas is at least 12,335 Ci (456 TBq).

Radioactive Waste Dumping in the Far Eastern Seas

Since 1986, low- and medium-activity solid radioactive waste have been regularly dumped in Far Eastern seas in four of the ten designated areas. Site No. 9 (Sea of Japan) is distinguished in terms of the amount of dumped solid radioactive waste and Site No. 8 (near the southeastern coast of Kamchatka) is noted for the highest total activity of low- and medium-activity solid radioactive waste. According to available data, the total activity of low- and medium-activity solid radioactive wastes dumped in the designated areas of the Far Eastern seas amounts to 6,851 Ci (254 TBq). The above activity occurs in 6,868 submerged containers—38 of them submerged ships, plus 100 other submerged large-scale objects.

The dynamics of low and medium solid waste dumped in the Far Eastern sea is presented in Figure 5. It follows from these data that the highest amount (in terms of activity) of such solid radioactive waste was dumped in 1975 and 1985.

According to the information, the activity of the radioactive waste dumped by the USSR in the Far Eastern seas is distributed thus: liquid radioactive waste, 12,337 Ci (456 TBq); solid radioactive waste of low- and medium-activity, about 6,112 Ci (225 TBq); and solid radioactive waste, including the activity in two reactors and one screen, is 116 Ci (4.3 TBq). The total amount is 18,565 Ci (685.3 TBq). No reactors with loaded nuclear fuel were dumped in the Far Eastern sea.

The above data should be supplemented by the information on radioactive waste transported to the Sea of Japan as a result of a nuclear submarine accident in Chazhma Bay, the loss of a 350 Ci radionuclide source near Sakhalin Island, and radioactive contamination from atmospheric deposition and river runoff.

With due regard for the vast territory of the Far Eastern water areas, liquid and solid radioactive waste dumped by the Pacific fleet evidently account for not more than a small percentage of the balance of manmade radioactive contamination.

Documented data and expert assessments allow us to estimate the total activity of radioactive waste dumped and disposed by the USSR in the seas washing the Russian territory as 325 KCi (12 PBq). From expert estimates, the upper limit of activity amounts to 2.5 MCi (92 PBq).

At present, the total activity of all radioactive waste sources transported through the World Ocean from USSR territory cannot be determined with sufficient accuracy because of a lack of certainty as to the inventory of all sources of radioactive contamination. Tentative data, largely of an expert nature, are provided in Table 3.

Unfortunately, the USSR's longtime practice of radioactive waste dumping in the seas was contin-

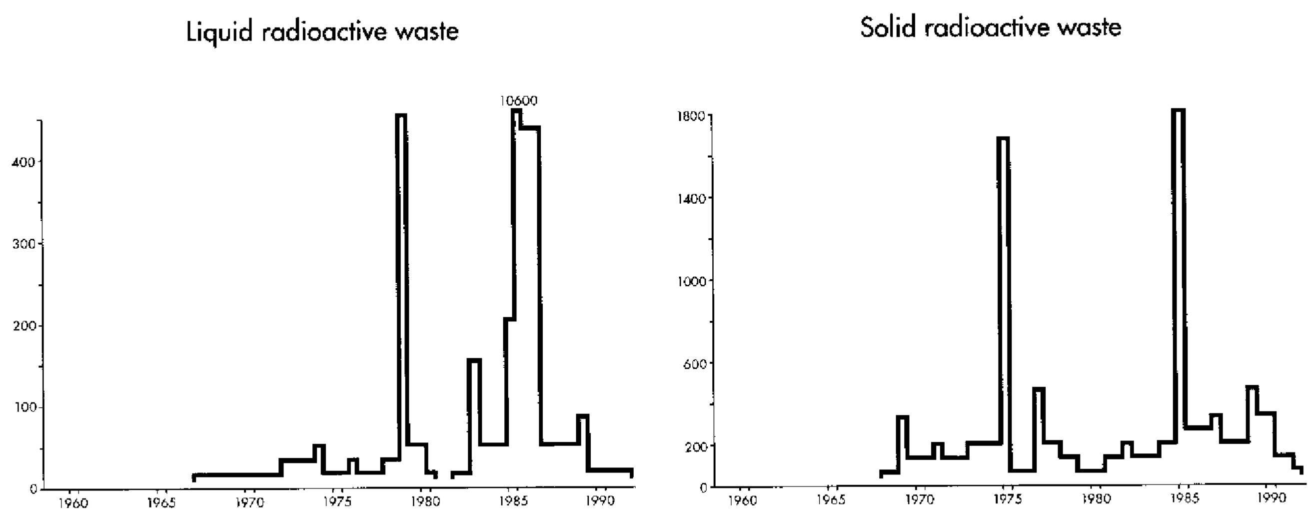


Figure 5. Dynamics of radioactive waste dumping in Far Eastern seas in different years.

Table 3. Master data on the scope of World Ocean contamination by radioactive waste from the Soviet territory during 1961–1990.

Contamination source	Location and date	Assumed total activity, KCi*
Liquid radioactive waste from Navy and MMSC	North Atlantic Northwest Pacific,	About 25 About 12
Solid radioactive waste from Navy and MMSC, including submerged reactors	Same	About 300 (expert estimate)
Sunken nuclear submarines	Atlantic and Pacific	Below 650
Lost nuclear ammunition, radio isotope fuel powered generators, satellites, etc.	Atlantic, Pacific, Indian Ocean	Several thousand
Radioactive waste runoff from the Yenisei and Ob	Arctic seas	Several tons
Total (upper limit)	Total World Ocean	Not more than 10,000

* For the time of dumping.

ued by the Russian Navy in 1992 in the Far Eastern and Northern seas. The total activity of 1990–1992 dumpings equals 55 Ci (2050 GBq).

Detailed radiological surveys of marine areas were carried out as part of scientific studies of nuclear waste dumping in 1960, 1966 and 1967, in 1972, 1980, and there was a research program on board vessels belonging to the Ministry of Defence, Roshydromet, and USSR Academy of Sciences.

In 1992, a joint Russian-Norwegian expedition conducted radiological research in the Barents and Kara Seas on board the scientific vessel Victor Buynitsky under the umbrella of the Ministry of Protection of the Environment and Natural Resources and the Norwegian Ministry of Environmental Education (Figure 6).

After 1965, radiation conditions were studied in water areas located at a distance of some 50 to 100 km from the sites of solid radioactive waste dumping. No studies of radiation conditions directly in the sites have been conducted for 25 years.

It should be noted that the dumping of radioactive waste in containers fails to guarantee absolute safety from the viewpoint of seawater pollution, since the containers are subject to corrosion. Metal containers disintegrate in a marine environment after ten years, reinforced ones after 30 years. The sealing capacity of the furfurol-based polymer used in many reactor compartments is insufficiently studied. All this requires regular control of the dynamics of dumped radioactive waste input to the marine environment.

The general state of radiation and sanitary hygienic monitoring of the radioactive waste dumping sites both in the Northern and Far Eastern seas in recent years should be considered unsatisfactory. In spite of the great amount of annually generated radioactive wastes, including highly active and potential hazardous ones, and their multi-year dumping in the seas, the system of observation and monitoring the radioactive objects dumped in the seas is practically nonexistent.

The Navy did not start setting up a system of marine radiation and environmental monitoring in dumping areas until 1992.

Radiation and hygienic surveys of solid radioactive waste dumping areas, carried out until 1967, and similar studies of liquid radioactive waste dumping areas conducted until 1990, revealed no cases of hazardous contamination of marine environment either at the dumping sites or the water areas.

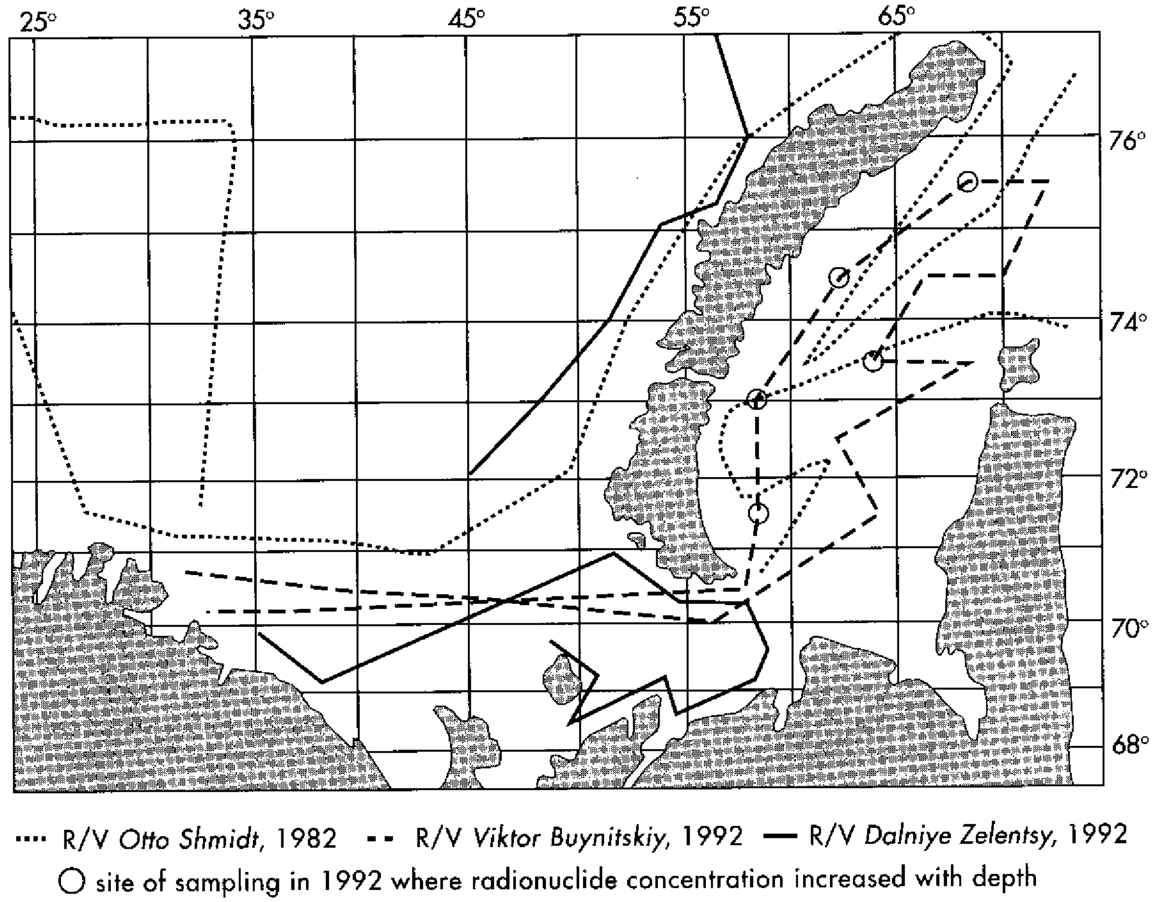


Figure 6. Routes of radiological research vessels studying radiation contamination in the Northern seas.

So far, current level of radioactive contamination in the Far Eastern and Northern seas do not manifest any hazardous increase in the marine content of radionuclides as compared to other Russian territorial waters (Table 4).

Therefore, preliminary studies allow a tentative conclusion that there is an absence of significant radiation hazards of liquid radioactive waste dumped from the facilities of the Northern and Pacific fleet and the Murmansk Marine Shipping Company, both for the population in general and population groups at special risk (fishermen, residents of coastal areas, etc.). Further investigation may refine the above tentative assessment of liquid radioactive waste effects, but are unlikely to change it significantly.

Assessment of effects of liquid radioactive waste dumping on the marine ecosystem and biocenoses is a more complicated matter. Our knowledge of the cycle of substances in the northern and polar ecosystems is too fragmentary to allow any final specific conclusions. For instance, our knowledge is entirely insufficient even in the field of hydrography. Recent discoveries of seasonally variable strong bottom currents and deep-sea storms, which transport water masses at speeds exceeding several knots, demonstrate the scope of our ignorance even with respect to seemingly well-studied marine parameters.

At the same time, balance calculations of liquid radioactive waste contribution (2.5–5.0%) to the total radiation contamination of marine ecosystems allow us to assume with reasonable certainty that liquid radioactive waste effects on marine ecosystems cannot be a determining negative factor in the scales of Northern and Far Eastern seas washing the Russian territory.

Analysis of the potential danger of radioactive wastes from ship-borne nuclear power units allows us to conclude that the greatest hazards in terms of radiation hygiene and radioecology are the reactors loaded with enriched nuclear fuel that were dumped in the Kara Sea. Considerable release of radionuclides for the coming period seems unlikely, since the dumped reactor compartments or reactors still containing nuclear fuel assemblies passed a special control procedure involving the enhancement of protective barriers (filling of internal cavities with furfurol-based polymer, concrete application, additional sealing, etc.). For instance, the calculated period of possible seal failure for the first nuclear unit on the *Lenin*, consisting of three reactors without nuclear fuel, is up to 500 years.

An urgent task, then, is to set up a reliable system to assure monitoring (observation, tracing, and analysis) of radionuclide release from dumped solid radioactive waste.

Russian Efforts to Comply With International Standards

Taking into account that all dumping of solid radioactive waste in the Northern seas (and some in the Far Eastern seas) was in violation of international standards, and with due regard for their potential radioecological danger, the only sound solution to the problem is to remove large-sized high-activity solid radioactive wastes from shallow dumping sites and redeposit them at burial sites on land. However, such a decision should follow integrated studies of radioactive risks related to these solid radioactive waste dumpings.

The Russian Ministry of Protection of Environment and Natural Resources, together with other regulating bodies, has recently bolstered its monitoring of radioactive waste dumpings in the sea by setting up a system for observations of radiation conditions in the areas of earlier dumpings. However, deep economic crises have led to substantial funding cuts, and the success of these activities is largely dependent on cooperation with other concerned countries and international organizations.

A draft of the Russian Federation state budget for the current and coming years envisions allocations of 0.3–0.4% for nature protection—values at least ten times lower than is spent for these purposes in any developed country. That is why the Ministry makes considerable efforts to ensure specific forms of cooperation with foreign experts, particularly on conducting joint studies of radioactive contamination in the seas and oceans and its effects on marine ecosystems and human health. In this respect, we are carrying out joint investigations with scientists and specialists from the United States, Finland, and Sweden. Negotiations are under way to carry out a joint marine expedition in the Sea of Japan and Okhotsk Sea, with Japanese experts. There are plans of cooperation with the Republic of Korea. Our cooperation with Norway serves as an example. The first Russian-

Table 4. Mean concentration of strontium–90 in surface marine waters during 1990–1991, KCi L^{-1}

Area	1990	1991	Number of samples in 1991
Baltic Sea	0.53–0.57	0.44–0.46	15
Azov Sea	0.85	0.83	5
White Sea	0.25	0.25	4
Barents Sea*	0.21	0.16	6
Caspian Sea (northern part)	0.40	0.33–2.35	13
Okhotsk Sea	0.09	0.10	4
Sea of Japan	0.17	0.10	4
Black Sea (Dnieper-Bug estuary)	—	2.1	14
Pacific Ocean (Eastern Kamchatka coastal waters)	0.08	0.09	12

* From data of 1992 Russian-Norwegian expedition. The Kara Sea is less contaminated than the Barents Sea (Survey, Draft 18/8–93, Oslo).

Norwegian expedition to the Kara and Barents Seas studied the areas around the Novaya Zemlya archipelago. Several days ago, the second Russian-Norwegian expedition took off. This time the route of the expedition encompasses most of the "hot spots" in the Russian territorial waters around Novaya Zemlya, including the areas close to the nuclear test site located there. It is worth noting that the activities involve the assistance of the International Atomic Energy Agency, which has opened a reliable channel to disseminate the data and scientific findings among all the countries concerned (Survey, Draft 18/8–93, Oslo).

Further plans of Russian-Norwegian cooperation involve studies of radioactive products transported to the Northern seas with a runoff from the Severnaya Dvina and other large Siberian rivers, particularly the Ob, which was turned into a kind of "nuclear cooking pot" for radioactive wastes from nuclear enterprises in Chelyabinsk, the well-known Mayak plant for nuclear fuel production and processing, and the no less familiar Tomsk–7 enterprise, where an accident involving the release of radioactive products took place this year.

CONCLUSION

There is documented evidence that since 1959, the USSR dumped radioactive wastes with various levels of activity. Dumping included radioactive waste generated by military and civilian ships equipped with nuclear power units. There are data on a considerable number of unauthorized and emergency submersions of nuclear units, including reactor compartments from nuclear submarines with loaded nuclear fuel. The Navy continued dumping liquid wastes in the Barents Sea and liquid and solid wastes in the Far Eastern seas until the year 1992.

Problems of radioactive waste dumping in the seas have become especially acute for Russia in terms of honoring its international obligations and ensuring its own environmental safety.

The new Russian Law on Environmental Protection (1991) does not allow radioactive waste dumping in the seas. Article 50 of this law completely prohibits radioactive waste dumping. Russia has also signed the relevant documents of the Conference on Environment and Development (Rio de Janeiro, 1992), the Convention on the Protection of the Marine Environment in the Baltic Sea and the Black Sea, and the London Convention. New democratic Russia expresses its resolution to live in compliance with the common principles and norms of international law.

These aspirations can be fulfilled only through open and sincere cooperation with other countries, financial and technical assistance in liquidating the consequences of radioactive waste dumping in the Arctic and Pacific seas, more detailed and broader studies of radioactive waste dumping sites in the seas, the establishment of an efficient monitoring system, immediate solution of the problems related to the processing and safe storage of radioactive waste generated during the operation of ships and vessels with nuclear power units, the construction of adequate storage units, and the introduction of new facilities for waste processing.

Following the request of the Ministry of the Protection of the Environment and Natural Resources—a request supported by other ministries and departments, including the Ministry of Defence—the Russian government has already adopted a number of decrees which completely prohibit solid radioactive waste dumping and envision the elimination of liquid radioactive waste dumping within the next few years.

REFERENCES

Ekologichesky Vestnik Rossii. 1992. Russian Federation Law on Environmental Protection, No.5 (in Russian).

Final results from the Russian-Norwegian 1992 expedition to the Barents and Kara Seas. 1993. A survey of artificial radionuclides in the Kara Sea. Draft 18/8–93, alr, Oslo.

Gromov V.V., A.I. Moskvin, and Yu.A. Sapozhnikov. 1985. Technogenous radioactivity in the World Ocean. M.: Energoatomizdat (in Russian).

IAEA Safety Series, 78. 1978. IAEA requirements to sea disposal of RW, Vienna.

IAEA TECDOC–588. 1990. Summarized answers of states to the IAEA circular questionnaire, Vienna.

IAEA TECDOC–588. March 1991. Inventory of radioactive material entering the marine environment: Sea disposal of radioactive waste.

Russian President Administration. 1993. Facts and problems related to the dumping of radioactive wastes in the seas washing the territory of the Russian Federation, Moscow (in Russian).

XXI Century Agenda. Report of the U.N. Conference on Environment and Development.

A/Conf. 151/26 Vol. II, Sec. 22. Safe and environmentally sound disposal of radioactive wastes, pp. 284–286.

Vakulovsky, S.M., A.I. Nikitin, and V.B. Chumichev. 1985. On the pollution of arctic seas by radioactive wastes from West European radiotechnical plants. Atomnaya energia, v. 58 (1985), No. 6, pp. 445–449 (in Russian).

DISCUSSION

*(**Yasuhiro Sugimori**, Tokai University.)*

In Japan about 20 years ago we also began dumping radioactive waste in the ocean. Our government wants to calculate how such radioactive waste disperses in the deep oceans. We tried to calculate the dispersal process in deep ocean areas of the Pacific Ocean. But the deep ocean saturation models are not completed so far, and we have to establish such calculation models. I would like to propose we collaborate, not as government to government, but as scientist to scientist in order to calculate how such ocean waste dumping can disperse in the whole ocean—both for small waste areas and for larger areas, including the deep oceans. That is our proposal to you. Thank you.

Kazakov. I share your concern, and I share your opinion about the difficulty in the solution of this problem which now provokes concern on the part of all countries surrounding the area where the nuclear waste was dumped. I agree that we need cooperation between scientists who deal with this issue. I have already mentioned that a joint Russian-Japanese working group has started its research in a bid to develop a program to study the possible aftermath of nuclear dumping in the areas of Russia and Japan (primarily the Sea of Okhotsk). Of course, we need to collect objective data on the dumping, both by Russia and others, including Japan. We still don't have complete and reliable data on Japanese nuclear dumpings. We could use this data to develop specific models on the transport of the nuclear waste at least in the areas of the sea which are now our concern. Perhaps in the near future we could speak about developing models for global policy on this issue. But today, I propose we start cooperation in concrete areas. It's not important if it is a governmental agreement or an agreement between universities. Scientists, researchers, and specialists need to work in governmental groups, too. This present forum allows us to see where exactly we can apply our effort and how we can start. Thank you.

*(**Nina Mollett**, University of Alaska Fairbanks.)*

The Soviet Union and our own government have been responsible for a lot of radioactive dumping of various sorts. I was thinking about the conversation we had yesterday about the Aleuts and the distance between science and ethics, between different specialties of science and putting it all together. Any child in the 1950s could have said that dumping radioactive matter in the oceans was stupid. Everyone knows that putting radioactive waste into the oceans is going to cause cancer, yet we have this incredible expertise which enables us to build these things, and to run our ships with them, and thousands of people who put their minds together to make this stuff, so we dump it anyway. Then it takes years to try to get rid of it. I think the anger many of us feel has to be expressed rather than just seeing these figures. It makes me angry to know that it might be dangerous to eat fish. It makes me angry to know the people responsible for the dumping went home to their families at night, to their small children, who were going to be eating the fish from the oceans where they were dumping. I just wanted to express a bit of anger here aside from the scientific discussion. Thank you.

Kazakov. That was an emotional speech, but it is just. The problem of nuclear waste dumping in the World Ocean will affect all of humanity. Today it's too late to point fingers as to who is to blame for the nuclear dumping. During the Cold War, governments were not really concerned with the children who would eat the nuclear-contaminated fish; they were concerned with creating more nuclear submarines. Our concern today is to minimize the consequences of the Cold War negligence.

*(**John Kelley**, University of Alaska Fairbanks.)*

Three weeks ago I had a cruise canceled on the Mendeleev because we wanted to go to the dumping sites on the eastern side of Novaya Zemlya. Can you tell me what modeling efforts, if you know, are currently under way to look at distribution of not only radioactive materials but perhaps other contaminants as well in the Kara and Barents seas?

Kazakov. Access to the nuclear dumping sites on Novaya Zemlya is limited because the nuclear proving ground is still functional there. You have to get government approval to go there. It is important that our joint efforts go through official channels. Our Ministry is now working to get permits from the Ministry of Defence, so we can manage to get access to most closed super top-secret high-risk areas where several years ago no foreigner would be allowed.

As far as the second part of your question, we do not have a special program to study the distribution of contaminants in those areas. In St. Petersburg, some research is being done to create a model on radioactive contamination of the seas of the Arctic Ocean. I also mentioned some serious research in Obminsk by the Typhoon Research and Industrial Company, studying the distribution of radioactive waste in the Northern and Barents seas. They have very reliable models, and I think they are accessible to the world scientific circles. I agree it's high time we thought about an international program to study the Kara and Barents seas and the Northern Sea, and perhaps the same program in the Pacific area, not only radioactive waste, but all kinds of contaminants. I will propose this idea to our government.

Thank you.

Pollution of the Coastal Zone in the Japan Inland Sea

Shiro Okabe
Tokai University
Tokyo, Japan

This report briefly summarizes observations of water pollution in the adjacent seas and inland sea of Japan from 1975 to 1981 by the Water Quality Bureau Environmental Agency of Japan, and reviews the matter as follows: first, the purpose, outline, and equipment used in the investigations are described; second, the items of investigation and the analytical methods for seawater, bottom sediments, and plankton are reviewed; and third, the pollution situation in the Japan inland sea is described, based on 1981 analyses.

OVERVIEW

The purpose of this study is to obtain comprehensive information on the state of pollution of the adjacent seas, in order to clarify mechanisms of marine pollution in view of the latest international movements, such as the Global Investigation of Pollution in the Marine Environment (GIPME) and the Western Pacific Region (WESTPAC) Task Team on Marine Pollution Research and Monitoring, recently carried out by UNESCO's Intergovernmental Oceanographic Commission (IOC).

Five observation lines (A-E; Figure 1) were set up, extending from the coast of Japan, across main currents to the open seas around Japan, and passing through toxic waste dumping sites designated under Japan's Maritime Pollution Prevention Law. Samples of seawater and sediments from 2,000 m to 4,000 m were taken at monitoring points on lines A–E for determination of concentrations of heavy metals and water column characteristics, including temperature, transparency, pH, dissolved oxygen, chemical oxygen demand (COD), total organic carbon (TOC), salinity, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, Kjeldahl-nitrogen, total phosphorus, phosphate-phosphorus, silicate-silicon, total mercury, arsenic, lead, cadmium, zinc, copper, polychlorinated biphenyls, hydrocarbons, and fluoride.

RESULTS AND DISCUSSION

Organic Pollutants in the Water Column

The average measured value of hydrocarbons in the various types of water was 0.11 ppb in the surface water and 0.14 ppb in the deep layer of the Japan Sea, Pacific, embayments, and Oyashio water (Figure 2).

The average concentration of total organic carbon in the various types of water (Figure 3) decreased from 1.0 ppm to 0.5 ppm, and water in bays exhibited a similar tendency (from 2.0 ppm to 1.5 ppm).

Metals in the Water Column

The average concentration of total mercury was 0.005 ppb and 0.004 ppb in all other types of water (Figure 4). There were no distinct differences for different depths and areas.

The average of measured cadmium value in the various types of water was 0.017 ppb in the surface layer and 0.037 ppb in the deep layer of the Japan Sea; 0.006 ppb in the surface layer, 0.061 ppb in the middle layer, and 0.080 ppb in the deep layer of the Pacific; 0.036 ppb in the Oyashio and 0.013 ppb in waters of embayments (Figure 5).

The average measured value of polychlorinated biphenyls in the various types of water was 0.23 ppt in the deep layer of the Japan Sea and Pacific, and 0.32 ppt within bays (Figure 6).

Metals in Sediments

All the measured values of total mercury in bottom sediments ranged from 0.005 to 0.600 ppm (Figure 7). The maximum value was observed at observation station T-1 in Tokyo Bay and values exceeding 0.1 ppm were obtained from Tokyo Bay (T-1 and 2), Osaka Bay (0-1, 2, 3, and 4), C-1, S-1, and D-3. Tokyo Bay, Osaka Bay, and the Seto Inland Sea exhibited higher values than in other sea

Table 1. The sedimentation rate of sediments in Osaka Bay.

Station	Accumulation rate S (cm y^{-1})	Sedimentation rate w (g cm^{-2} y^{-1})
42C	0.58	0.31
59G	0.18	0.085
40C	0.26	0.13
47C	0.61	0.34
52G	0.12	0.067

areas. Station D-3, which tended to show higher values in the open sea areas in previous years, showed the highest value of (0.810 ppm).

All the measured values of cadmium in bottom sediments ranged from 0.01 to 1.80 ppm (Figure 8). The maximum value was obtained at station T-1 (Tokyo Bay) and S-1 (Seto Inland Sea); other stations where values over 0.3 ppm were O-1 (Osaka Bay), E-5, and 6 (Japan Sea).

Organics in Sediments

All measured values of polychlorinated biphenyls in bottom sediments ranged from 0.9 to 252 ppb and the maximum value were obtained at the stations T-1 and 4 (Tokyo Bay) and O-1 (Osaka Bay) (Figure 9).

All measured values of hydrocarbons in bottom sediments ranged from 0.31 to 110 ppm and the maximum value was obtained at station T-1 (Tokyo Bay) and S-1 (Seto Inland Sea) (Figure 10).

Sedimentation Rates

The distribution of recent sedimentation rates has been determined in Tokyo Bay and Osaka Bay sediment cores using the ^{210}Pb method (Figure 11). The measured values of sedimentation rate in Tokyo Bay were within the range of 0.2 to 0.5 g cm^{-2} y^{-1}. Greater values were found in the western part compared with the eastern part of the bay. In Osaka Bay (Figure 12), rates ranged from 0.1 to 0.3 g cm^{-2} y^{-1} (Table 1). The sedimentation rates obtained in the inner portion of the bay were higher than at the outer sites.

Figure 13 shows the distribution of elements in sediment cores from Tokyo Bay as a function of the depth (time since deposition) obtained by ^{210}Pb dating. Metal content increased from about 1880 to 1970 when the highest concentrations were found, but more recently metal content has decreased gradually. This is attributable to the fact that the materials discharged from land into the sea were reduced in compliance with the Marine Environmental Protection Law concerning inland sea waters.

PLANKTON AND NUTRIENTS

Recent examination was also made of the relation between the distribution of red tide phytoplankton in coastal waters and the accumulation of organic substances on the bottom. Red tide phytoplankton frequently appear in Tokyo Bay, Lake Hamana, Ise Bay, and Seto Inland Sea. Figure 14 shows the number of occurrences of red tide phytoplankton in these four bays for the years 1978–1992. The number of occurrences of red tide in Seto Inland Sea and Ise Bay gradually decreased, but Tokyo Bay and Osaka Bay did not vary much during the 15 years of the study.

Several investigations of primary production indicated that nitrogen (Figure 15) and phosphorus (Figure 16) nutrients were supplied by the circulation in the water column. However, comparison between nutrients directly from the land and those released from sediments, shows that the former are about twice as large as the latter. It follows that the organic pollution in the bays may be reduced gradually, if land-based nutrient sources are controlled as much as possible.

The oxygen deficiency of the bottom layer of the eutrophic Inland Sea is exerting adverse effects on marine organisms. One of the causes is the death and decomposition of phyto- and zooplankton blooms. We can see the occurrence of anoxic water in the bottom layers of Tokyo Bay, Lake Hamana, Kagoshima Bay, Seto Inland Sea, and Omura Bay.

It is interesting to observe the horizontal distribution of nearly anoxic bottom seawaters in August and September from 1981 to 1985 in Omura Bay. Thermal stratification begins gradually in the central part of the bay in May when the difference in water temperature between the surface and bottom increases. Oxygen deficient water in

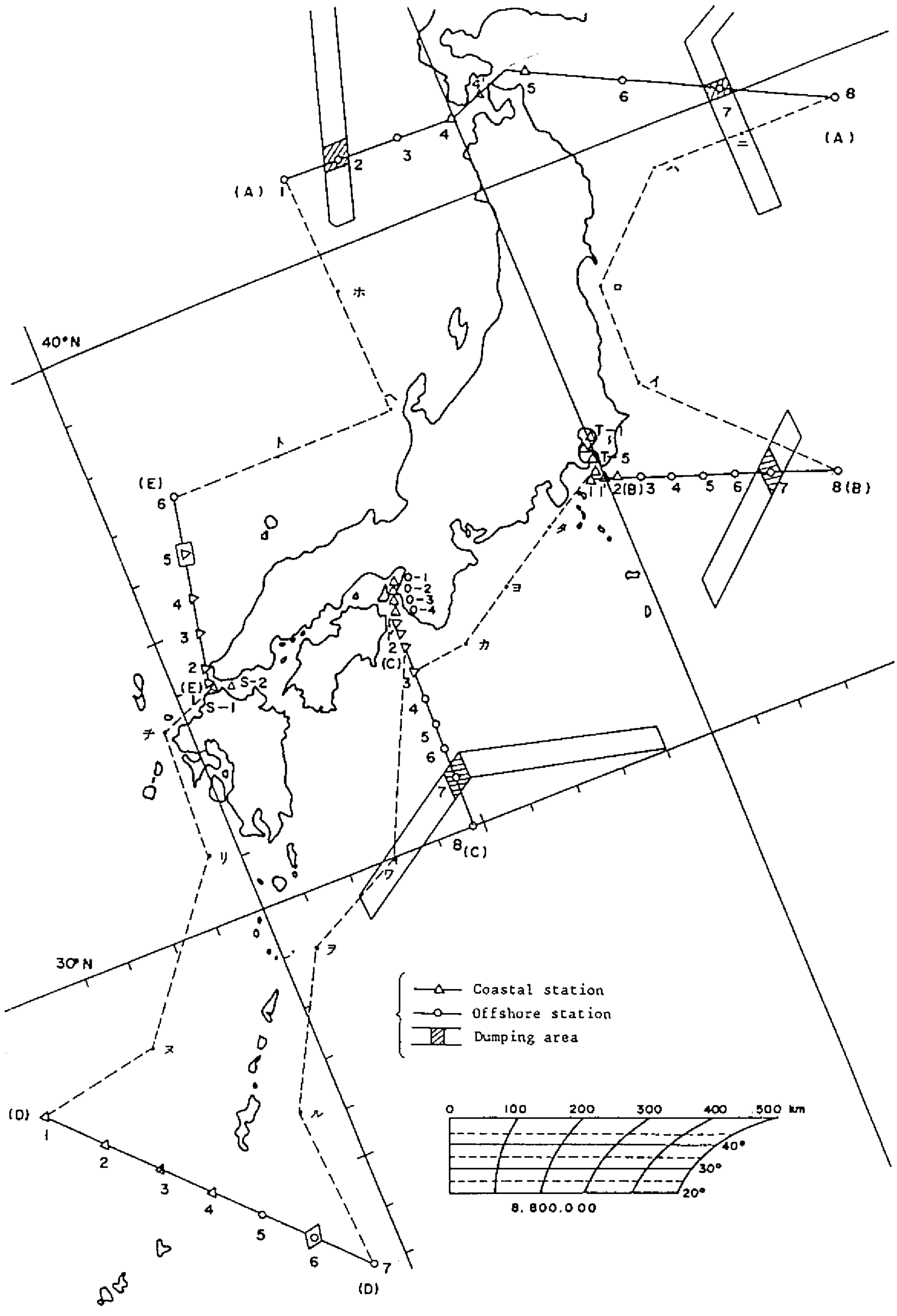


Figure 1. Observation stations, adjacent seas, and Inland Sea of Japan.

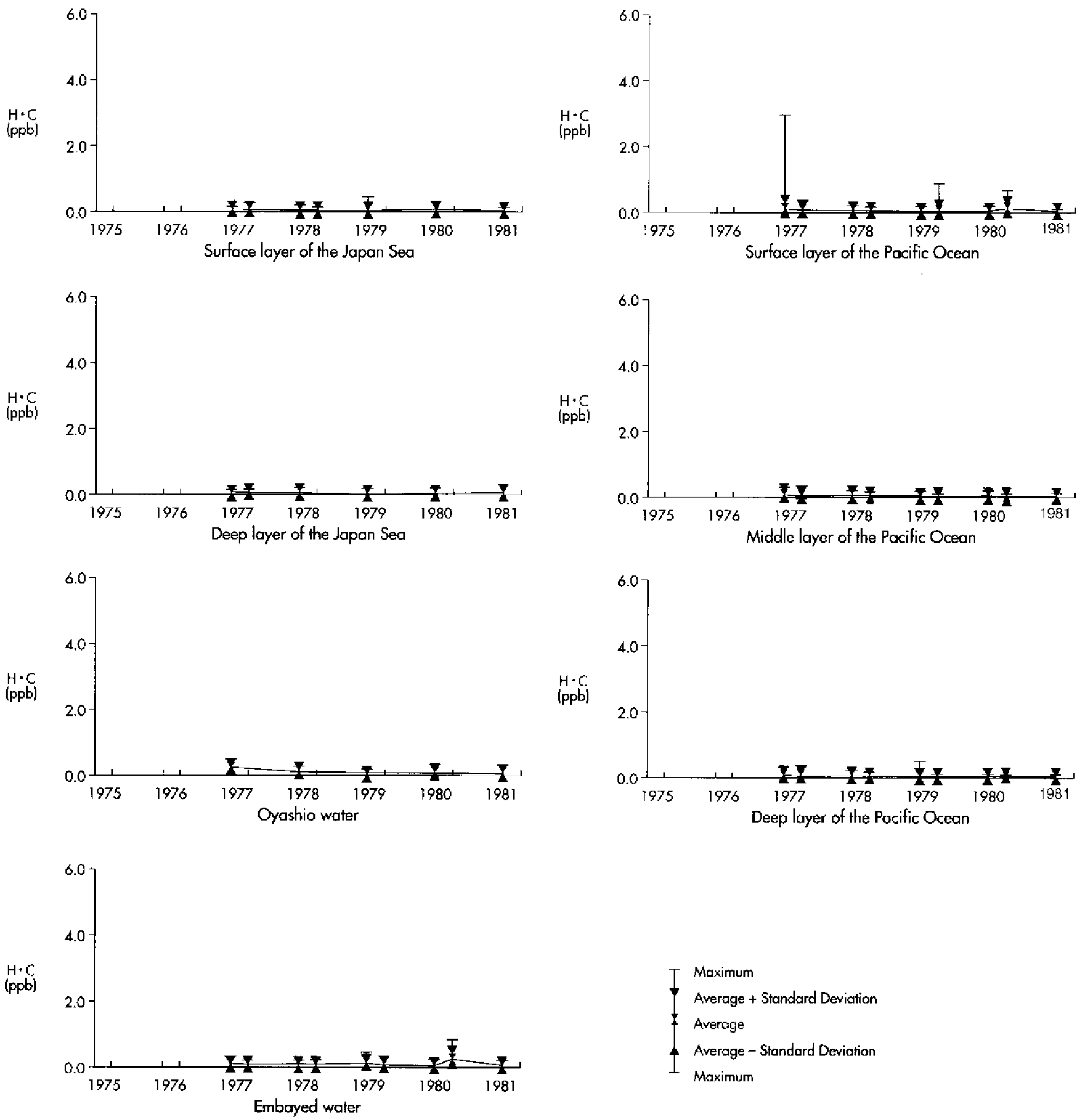


Figure 2. Secular changes in hydrocarbons in marine waters.

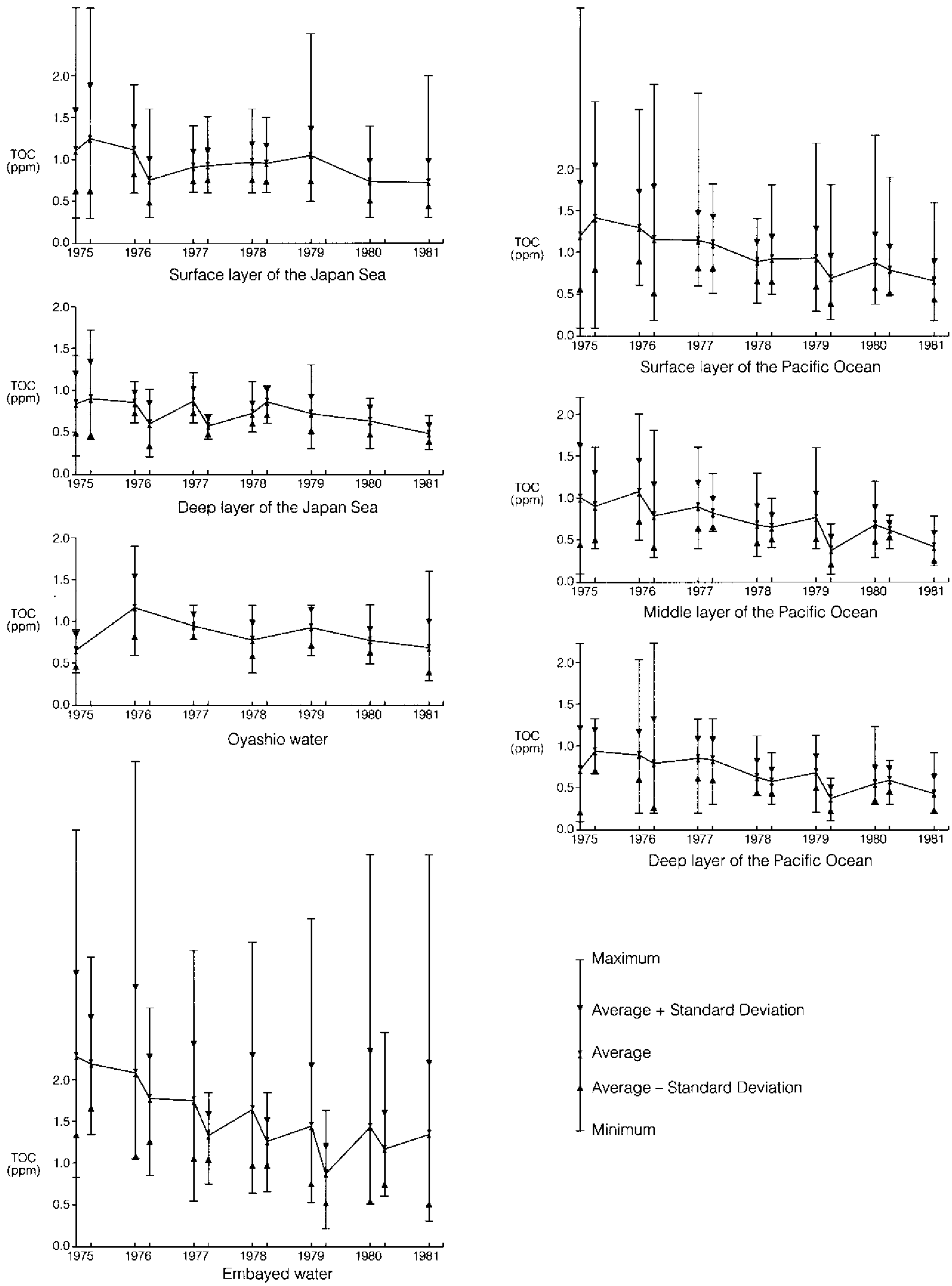


Figure 3. Secular changes in total organic carbon in marine waters.

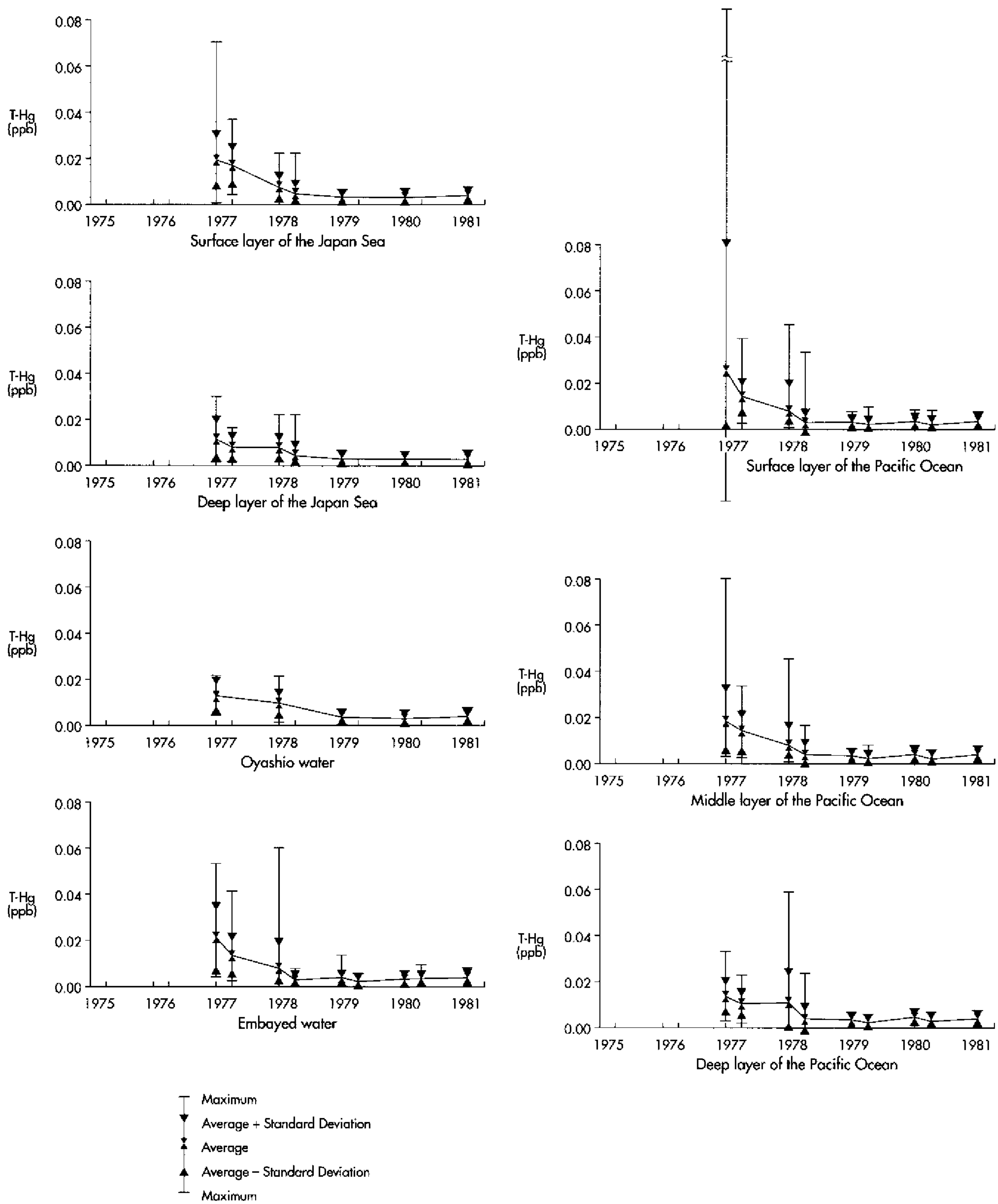


Figure 4. Secular changes in total mercury in marine waters.

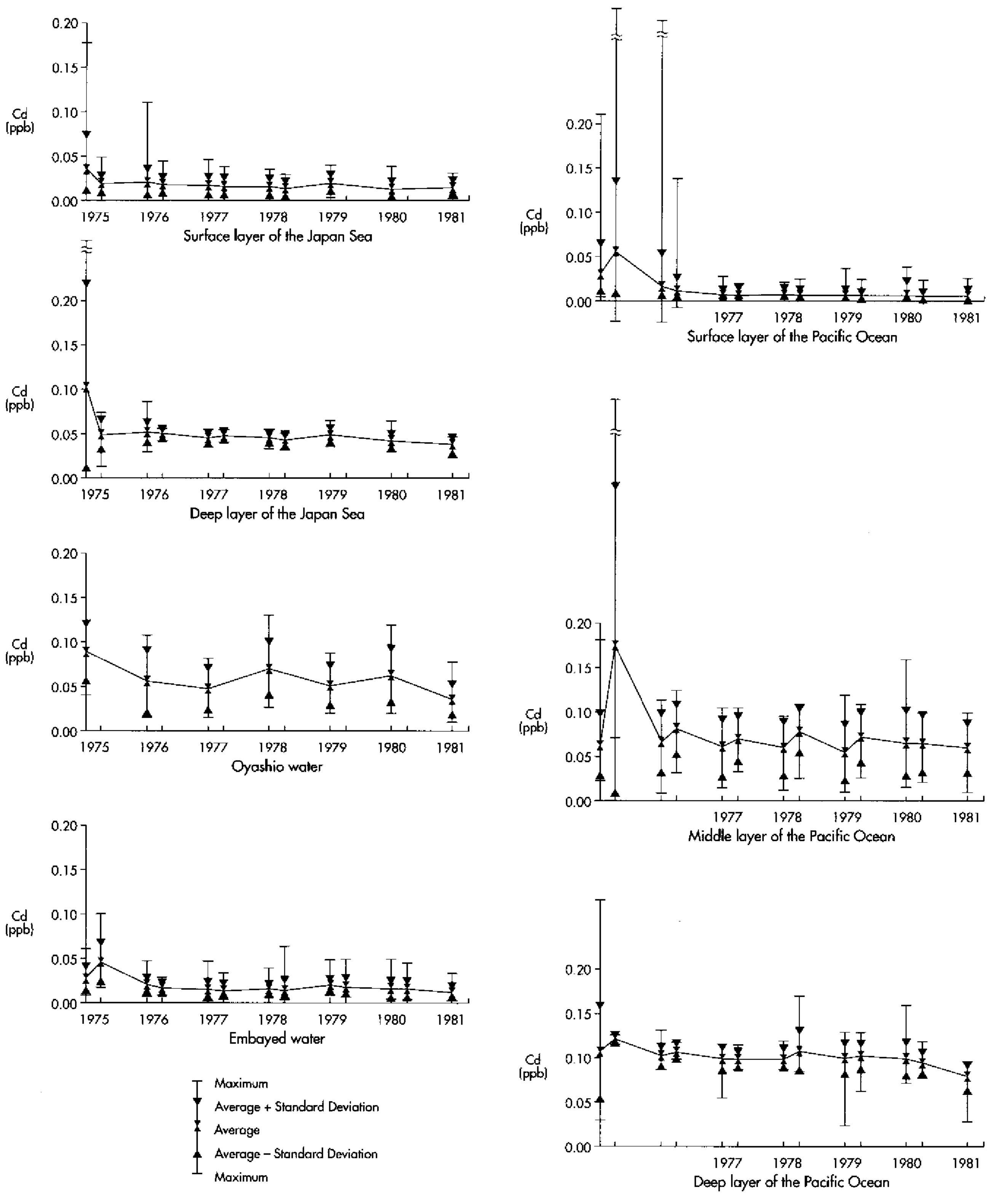


Figure 5. Secular changes in cadmium in marine waters.

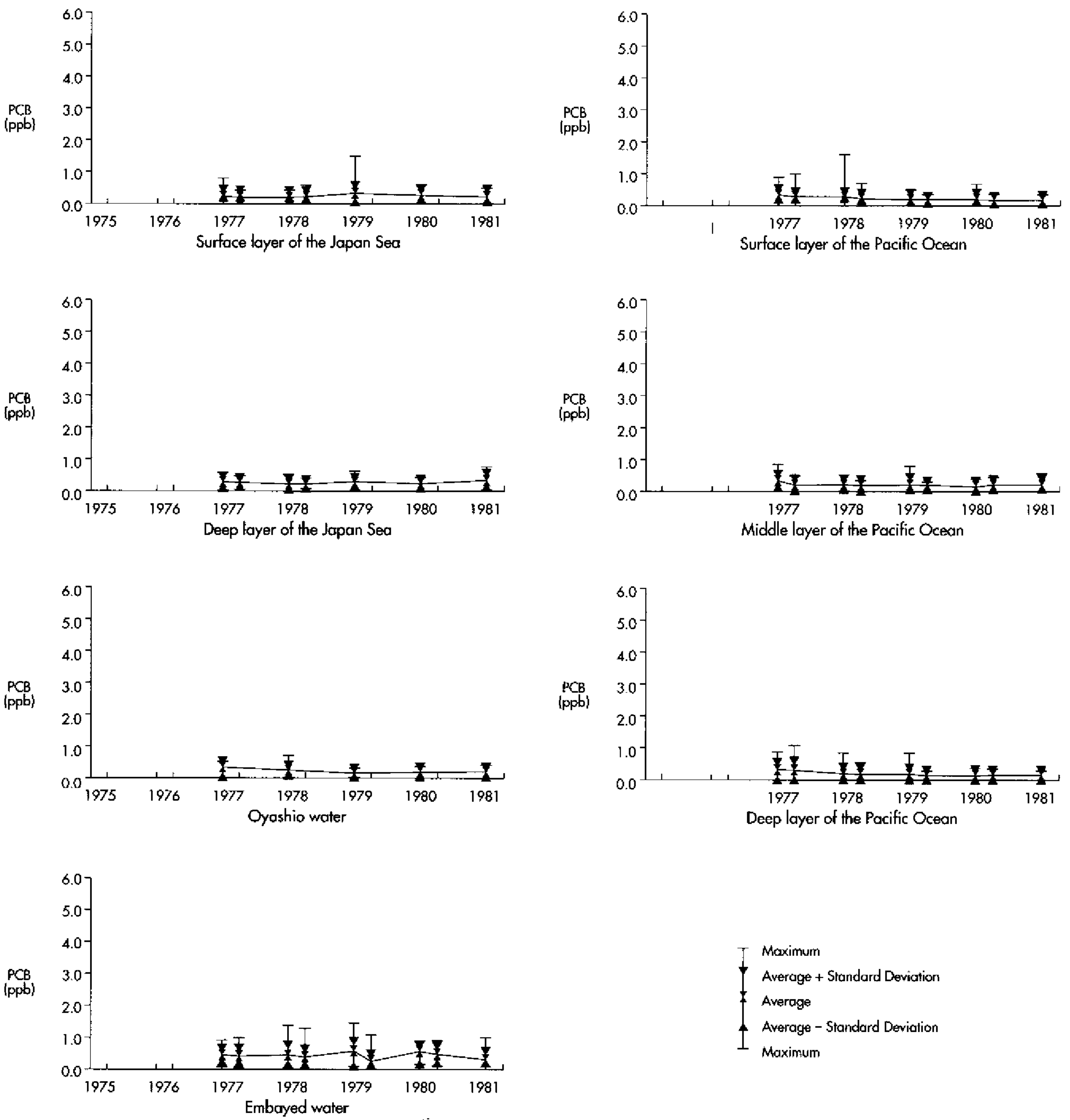


Figure 6. Secular changes in PCB in marine waters.

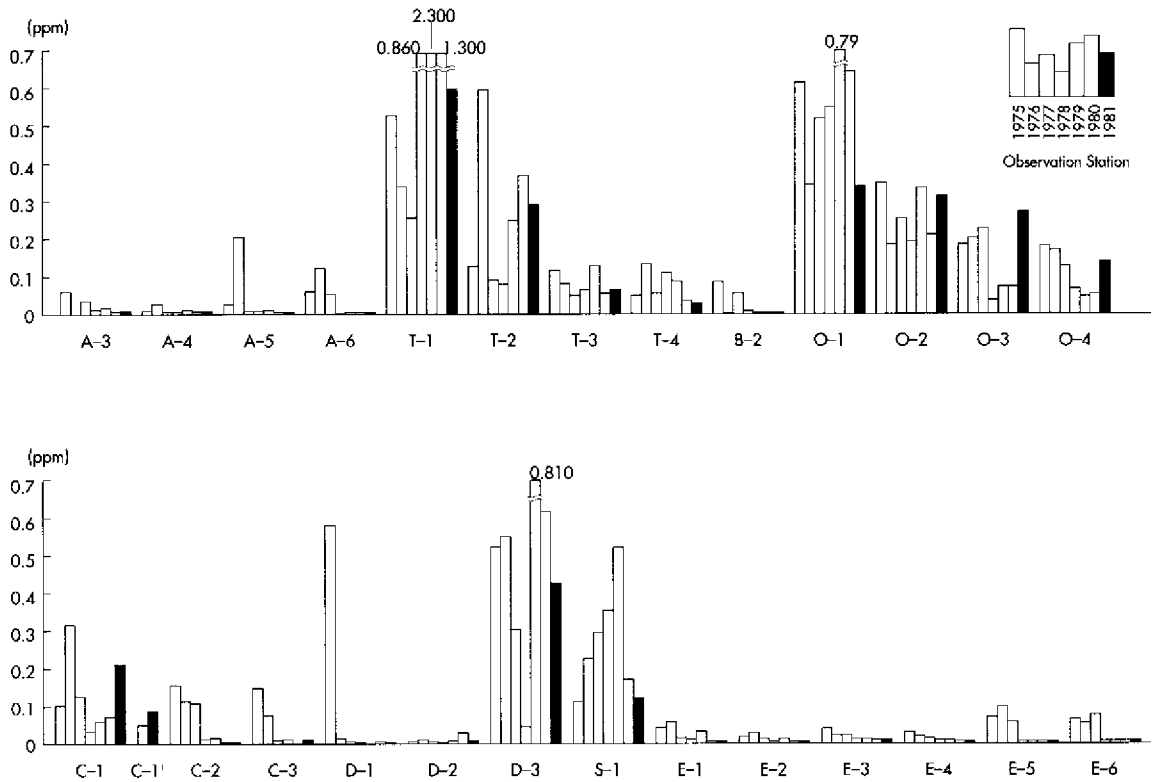


Figure 7. Comparison of yearly measured values of bottom sediments (total mercury).

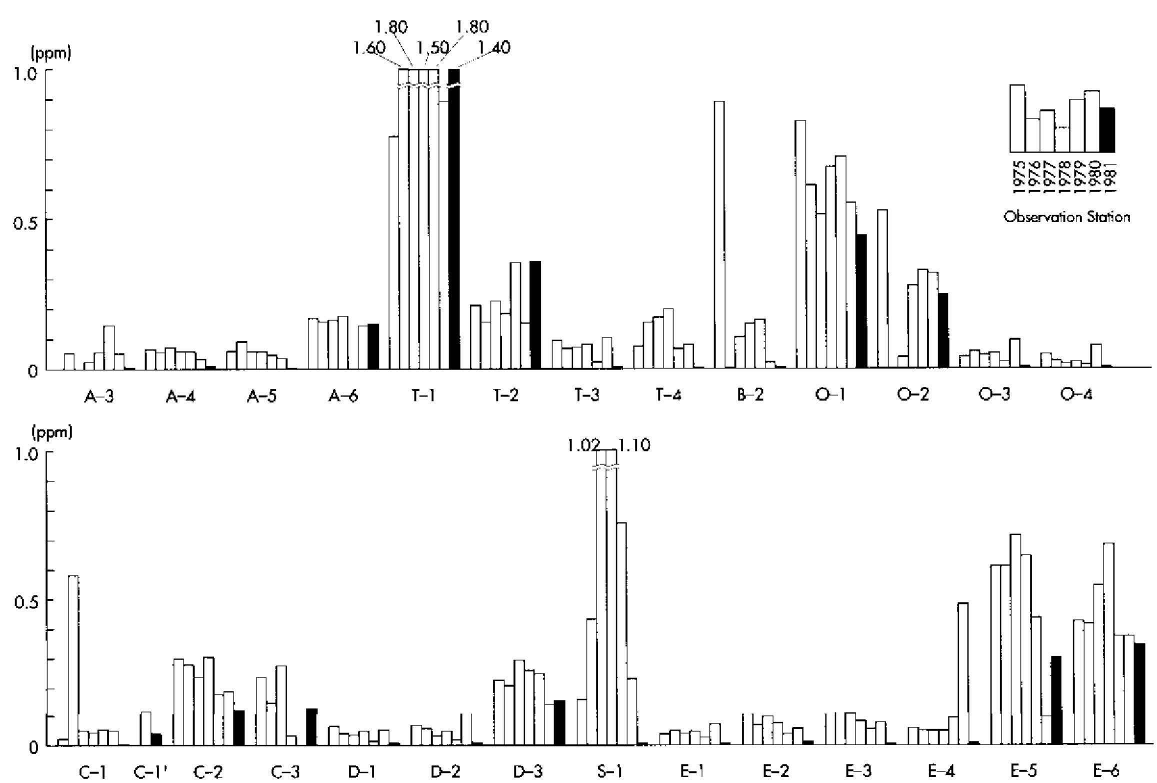


Figure 8. Comparison of yearly measured values of bottom sediments (cadmium).

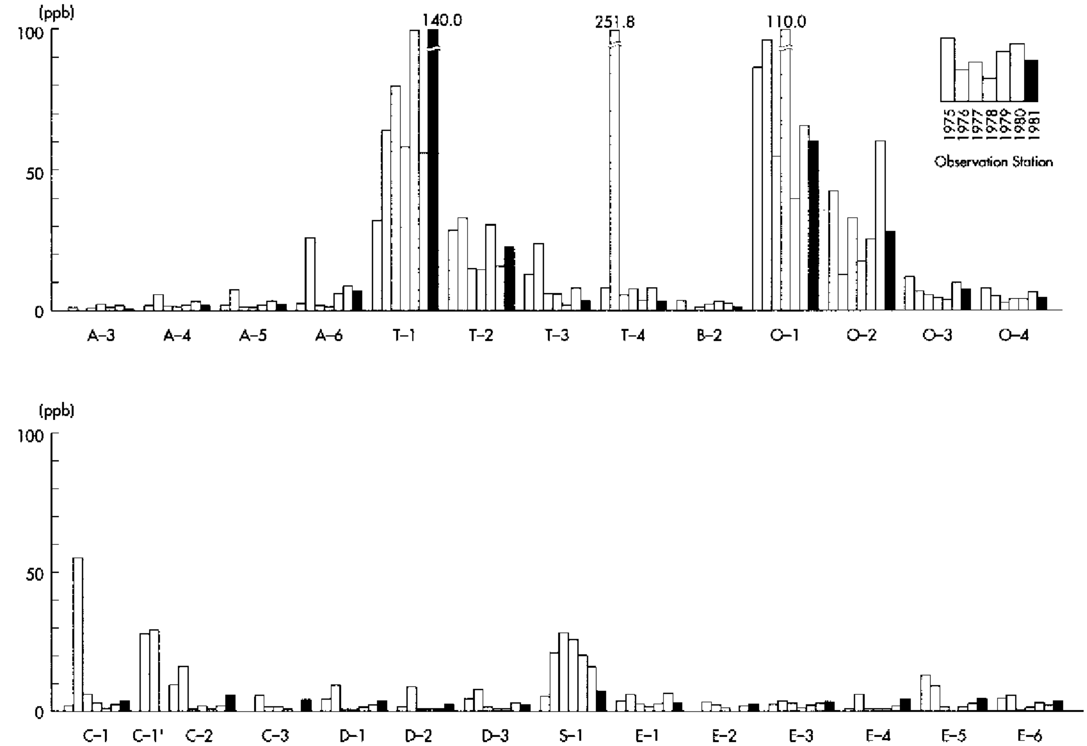


Figure 9. Comparison of yearly measured values of bottom sediments (PCB).

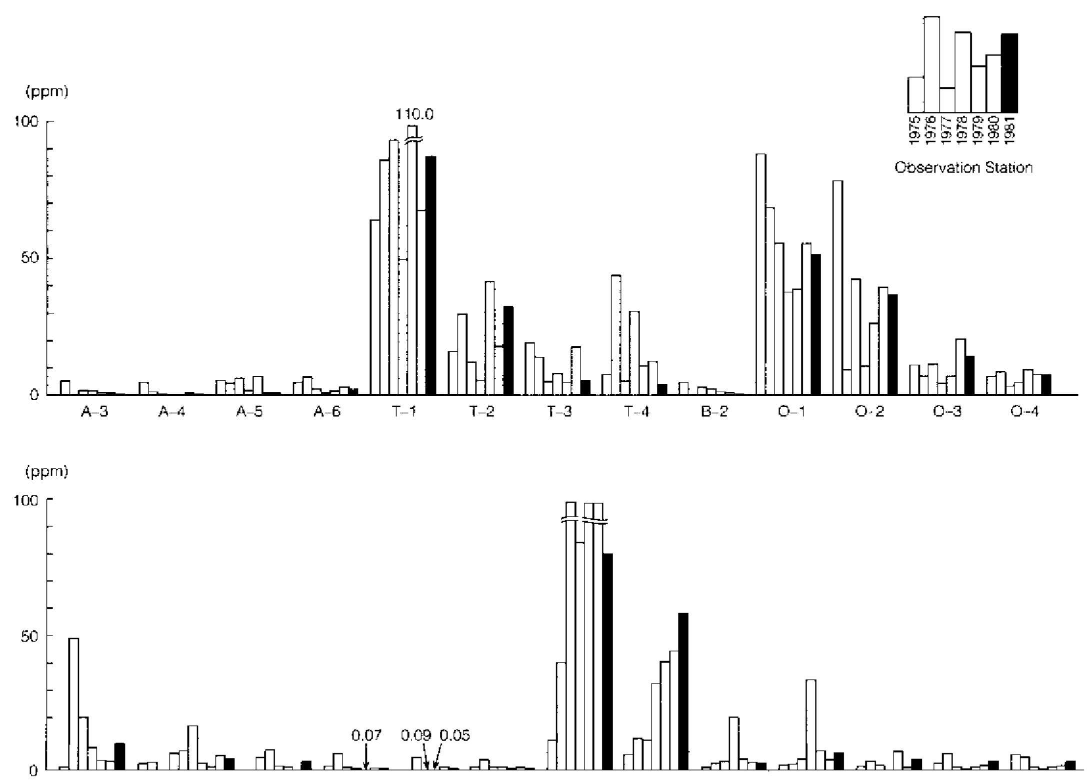


Figure 10. Comparison of yearly measured values of bottom sediments (hydrocarbons).

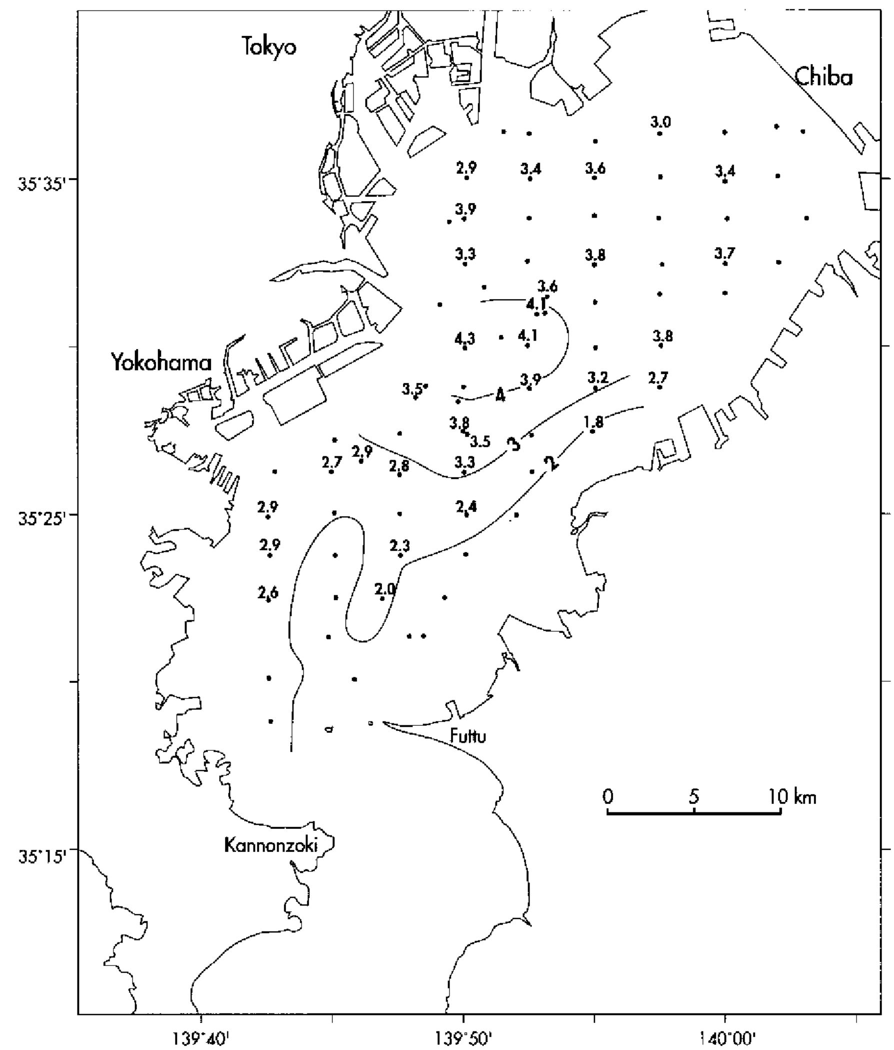


Figure 11. Recent sediment rate ($g\ cm^{-2}y^{-1}$) in Tokyo Bay determined by ^{210}Pb method (Matsumoto, 1983).

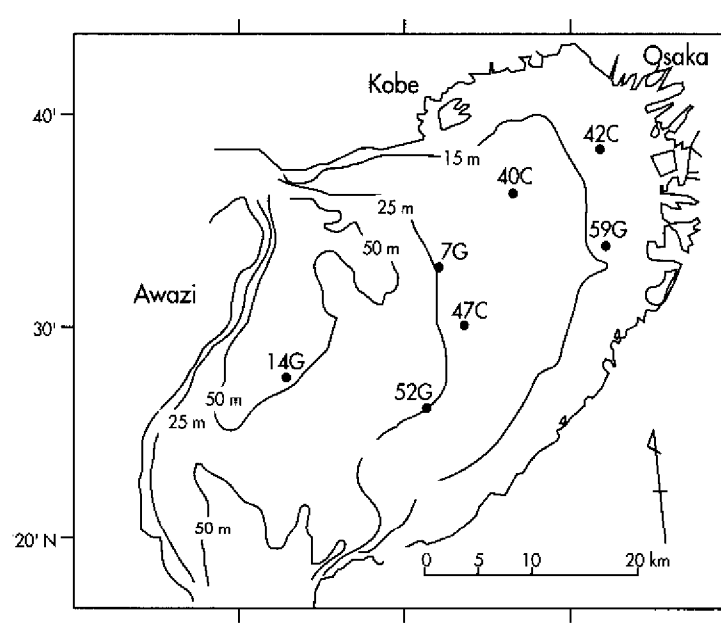


Figure 12. Location of sediment core sampling in Osaka Bay.

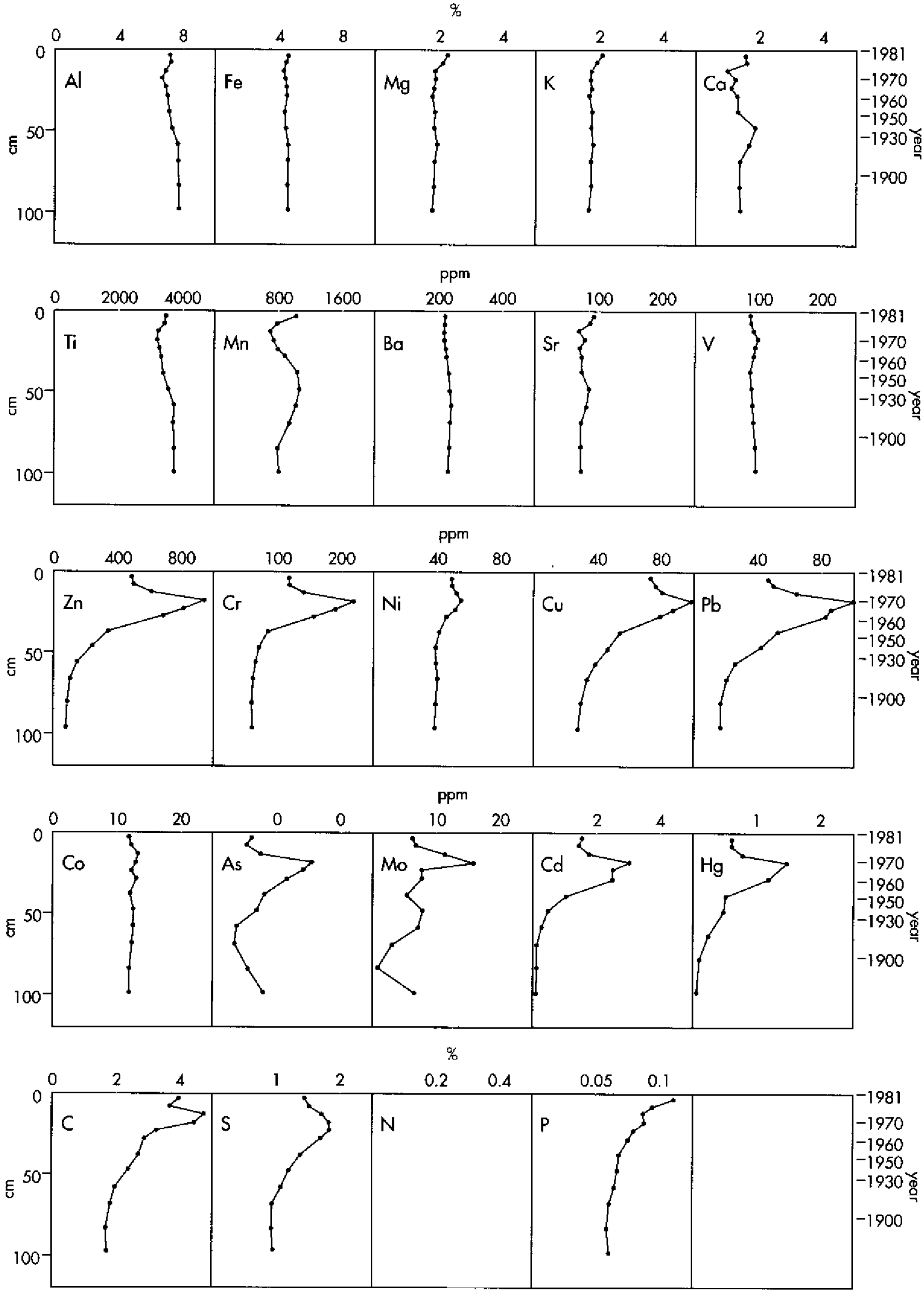


Figure 13. Distribution of element contents in the sediment core from Tokyo Bay as a function of depth or time. Dates were obtained by ^{210}Pb method (Matsumoto, 1983).

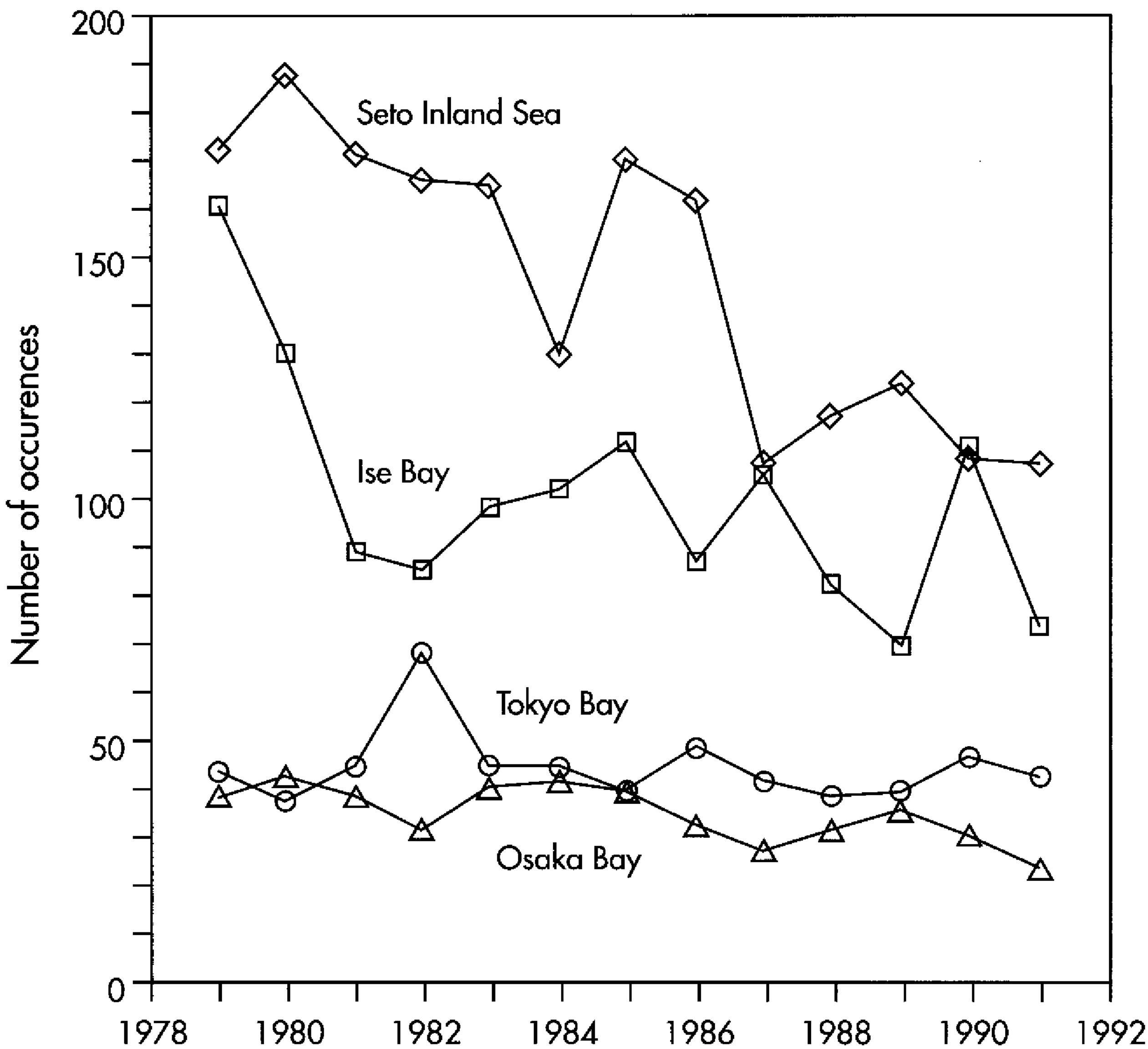


Figure 14. Number of occurrences of red tide phytoplankton.

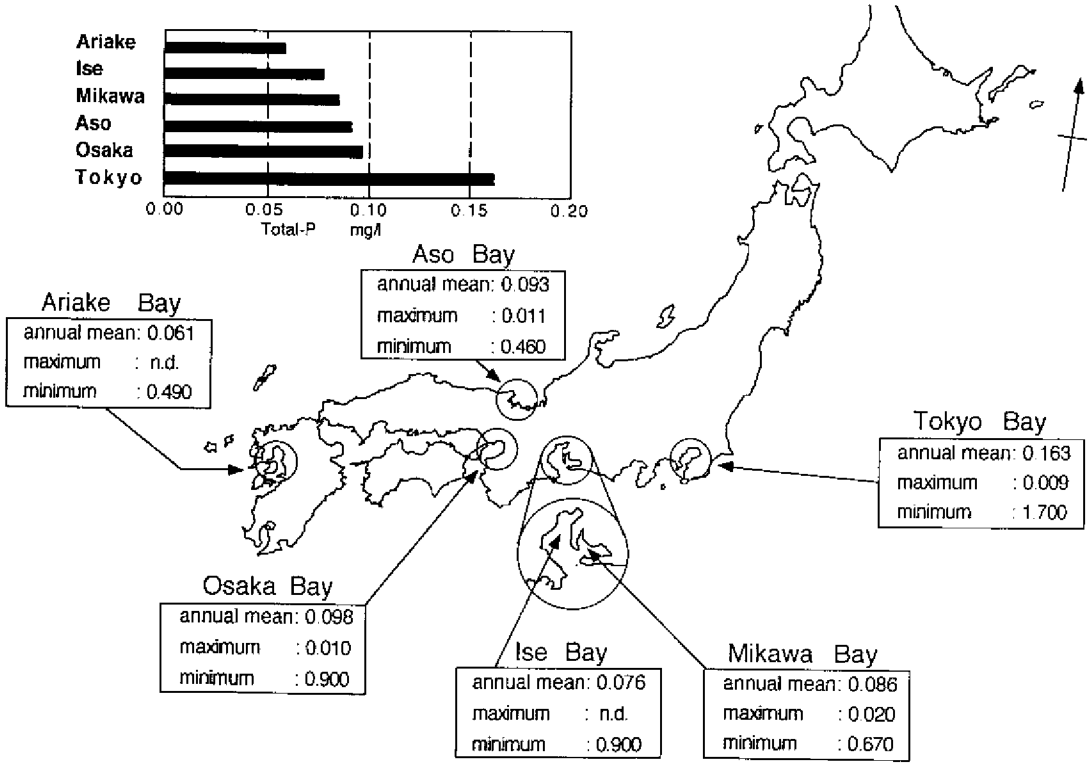


Figure 15. Annual mean values of total phosphorus (mg/l), 1987–1989.

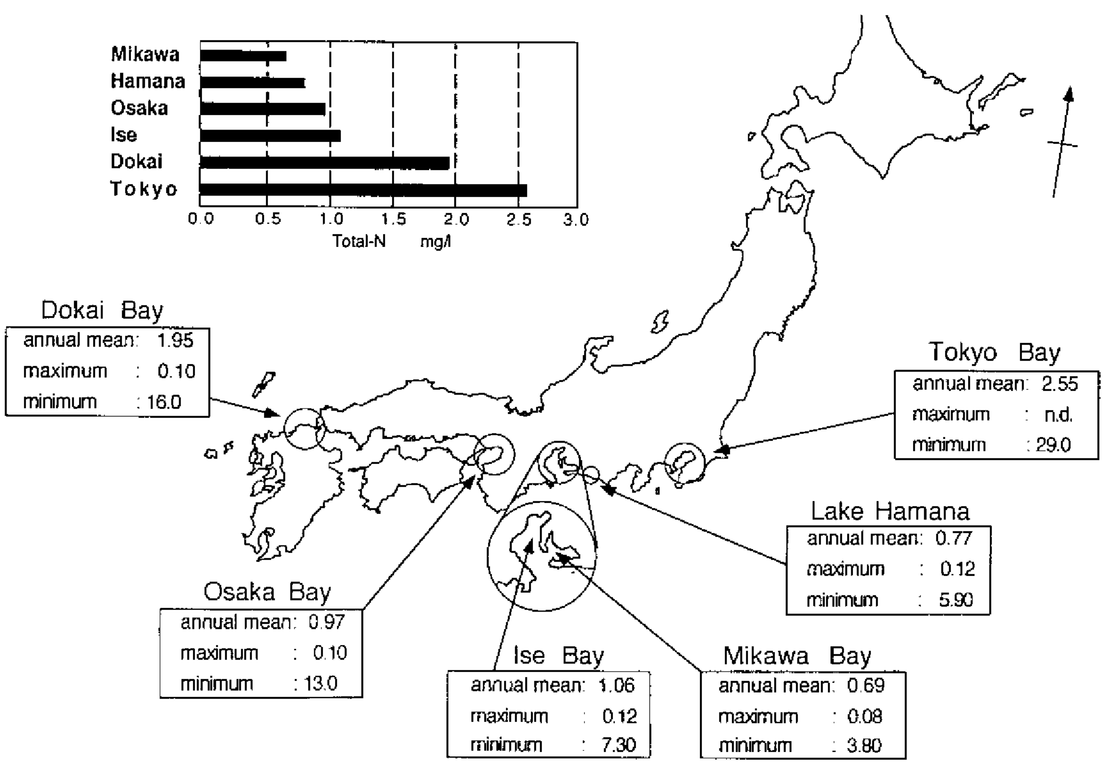


Figure 16. Annual mean values of total nitrogen (mg/l), 1987–1989.

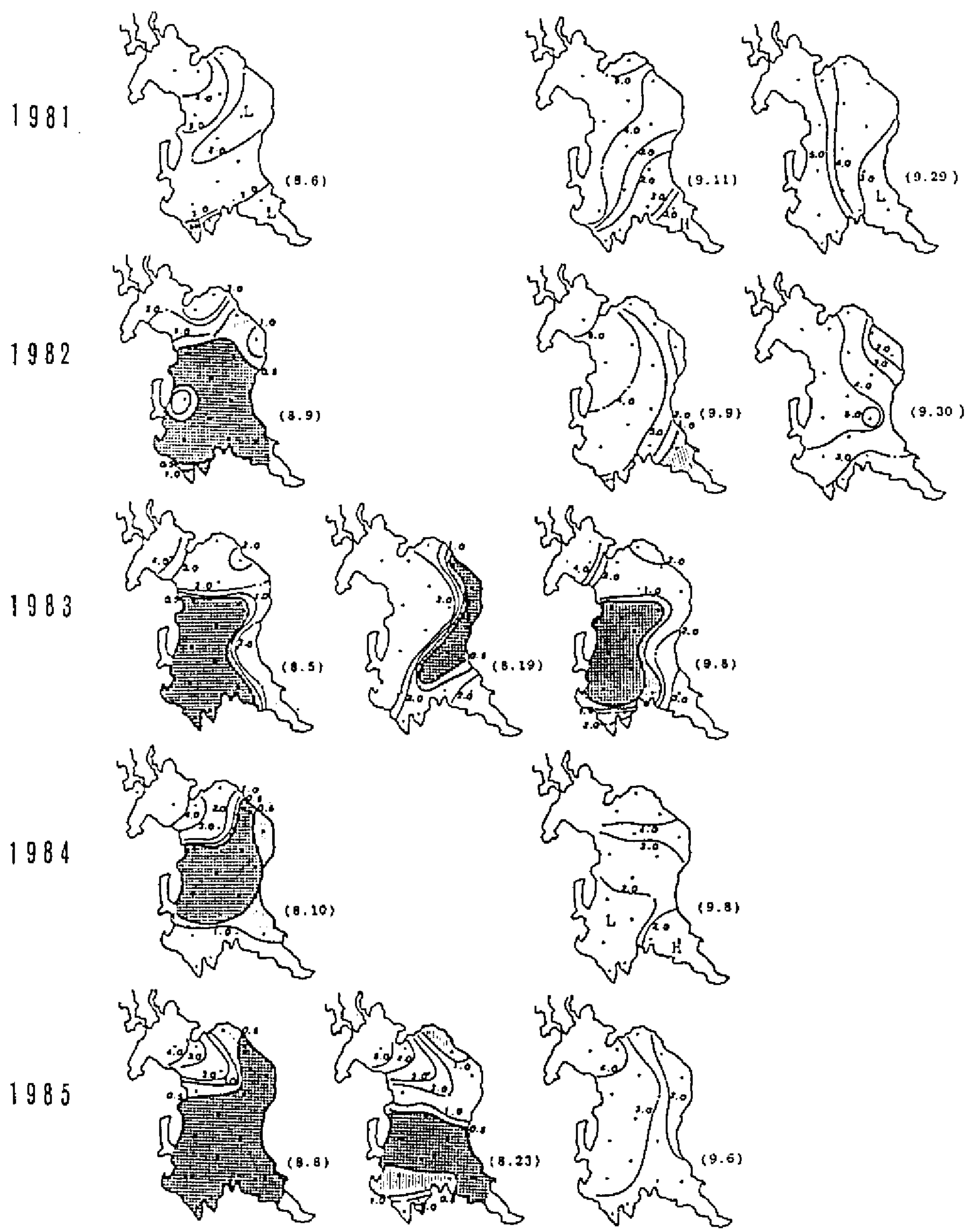


Figure 17. Horizontal distribution of the nearly anoxic bottom seawaters in August and September, 1976–1980. Striped patterns indicate waters 0.5–1.0 ml / l of the oxygen content and checkered patterns indicate waters less than 0.5 ml / l, including anoxic waters.

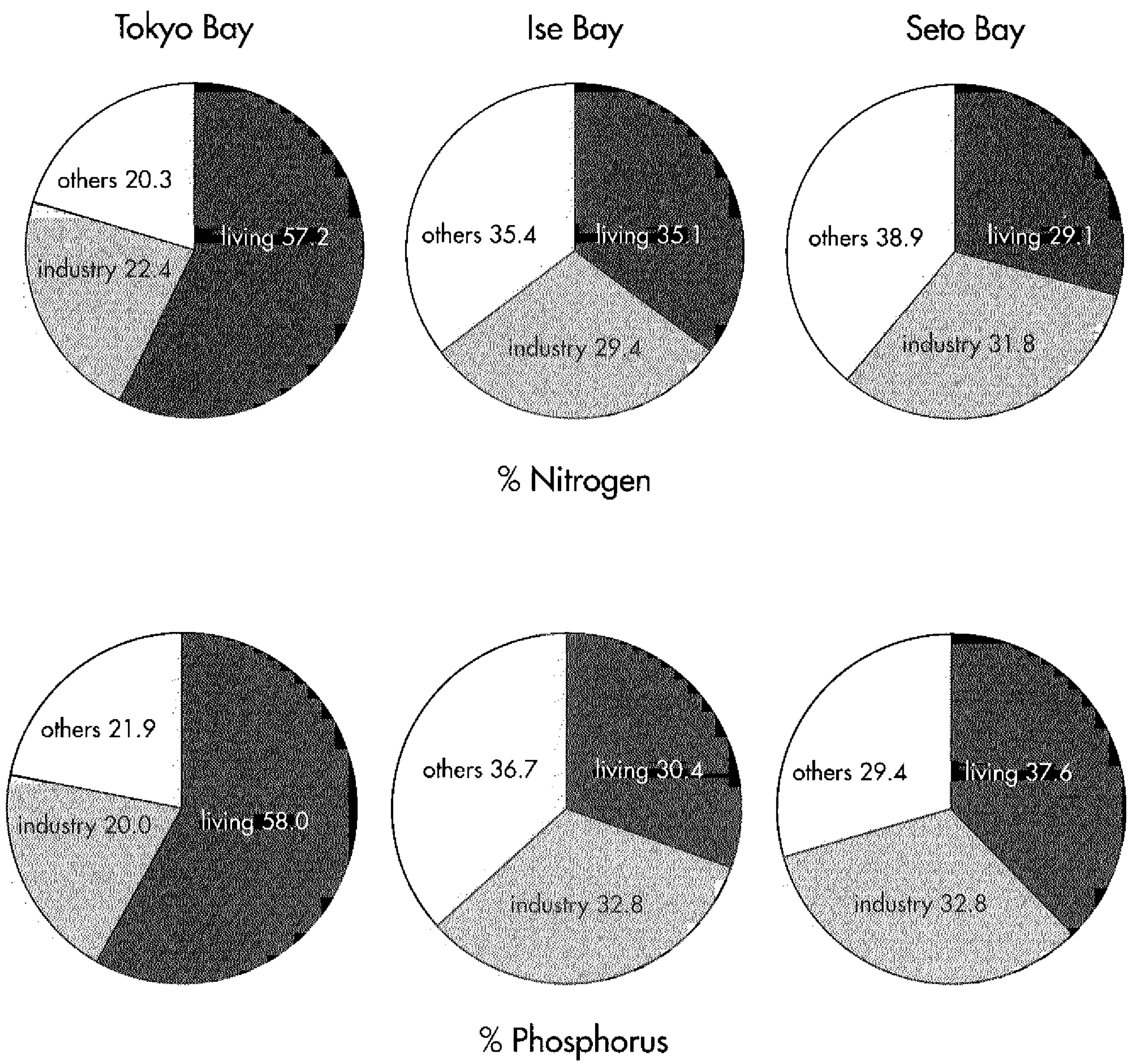


Figure 18. Nitrogen and phosphorus loaded into the waters of Tokyo Bay, Osaka Bay, and Seto Inland Sea (1989).

the bottom layer is formed every summer. In August, oxygen deficiency is greatest. Phosphate and ammonium are released from the bottom sediments under these anaerobic conditions. Formation of an oxygen-deficient water mass during summer influences marine biology in the bay. Marine biological resources are damaged by the upwelling of the bottom water (Figure 17).

Finally, we consider the nitrogen and phosphorus in the waters of Tokyo Bay, Osaka Bay, and Seto Inland Sea. They are as follows (Figure 18). In Tokyo Bay, biological sources account for about 60% of the total discharged nitrogen and phosphorus, industry for 20%, and others for 20%, respectively. In Ise Bay and Seto Inland Sea, the present percentage of biological sources is smaller that that in Tokyo Bay, accounting for 30% to 40% of total nitrogen and phosphorus. Thus, it appears that it will be necessary to reduce the biological sources of nutrients in the near future.

REFERENCES

Lizuka, S. and S.H. Min. 1989. Formation of anoxic bottom waters in Omura Bay. Bull. Coast. Oceanogr. 26:75–86.

Matsumoto, E. 1983. The sedimentary environment in the Tokyo Bay. Geochemistry (in Japanese) 17:27–32.

Matsumoto, E. and S. Yokota. 1977. Records of pollution in Tokyo Bay sediments. Geochemistry (in Japanese) 11:51–57.

Matsumoto, E. and S. Yokota. 1977. Accumulation rate and heavy metal pollution in Osaka Bay sediments. J. Oceanogr. Soc. Japan 34:108–115.

Water Quality Bureau Environment Agency. 1983. Summary of the investigation of pollution in the adjacent seas of Japan, pp. 1–61. Office of Marine Pollution Control and Waste Management, Tokyo.

Tracking the Flow of Waste Materials in the Pacific Ocean

Toshibumi Sakata, Haruhisa Shimoda, and Kohei Cho
Tokai University
Tokyo, Japan

INTRODUCTION

At the Third Asian Pacific University Presidents Conference held in Vladivostok in August 1991, Dr. Tatsuro Matsumae, president of Tokai University, proposed that universities work together to preserve the environment of the North Pacific Ocean. In January 1992, the Marine Environment Project/North Pacific Meeting was held at the Tokai University Pacific Center in Hawaii. At this meeting, it was agreed to start the North Pacific Ocean Environment Protection Project by using earth observation satellites.

In order to protect the health of the Pacific Ocean, Tokai University embarked on the Marine Environment Project. In this project, buoys carrying transmitters have been released in the North Pacific and tracked by the U.S. National Oceanic and Atmospheric Administration (NOAA) ARGOS system to trace the flow of waste materials in the ocean. The goal of this project is to find the final destination of the waste materials and contribute to making the seas cleaner.

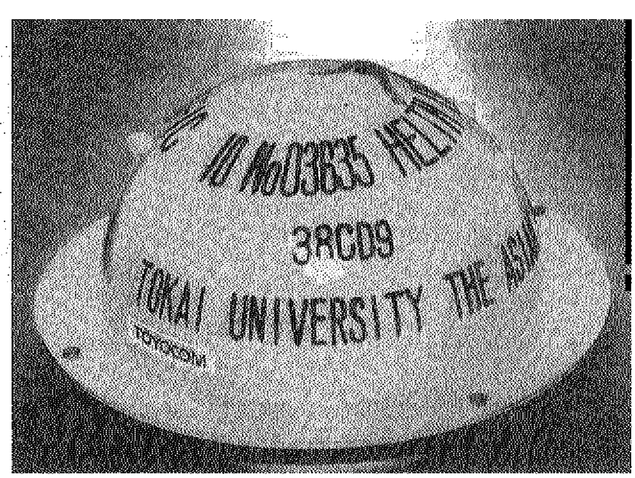


Figure 1. Buoy used in tracking study.

As a part of this project, in October and November 1992 Tokai University deployed a number of buoys carrying transmitters in the western part of the North Pacific Ocean and started tracking them using the NOAA ARGOS system to trace the flow of waste materials in the ocean.

In this study, flow routes and the speed of buoys were derived from ARGOS buoy-tracking data and buoy trajectories were overlaid on sea surface temperature images of NOAA and the geostationary meteorological satellite (GMS). The initial results show a positive relationship between sea surface temperature distribution and flow routes of buoys. Satellite images have helped us understand the mechanism of buoy drift caused by complex sea currents.

ARGOS BUOY TRACKING

Figure 1 shows a buoy used in this study. Each buoy carries a transmitter which allows the NOAA ARGOS system to track the buoy location (see Figure 2).

For the first stage of this project, a total of thirteen buoys were released in the North Pacific Ocean near Japan in October and November 1992. Figure 3 shows the overall trajectories of the buoys through the end of May 1993. Three were released at point A, four at point B, and six at point C. All the buoys drifted toward the east in the Kuroshio Current extension between approximately 30° to 40° North latitude except for one, which either drifted or was carried to Taiwan.

The drift rate of the buoys changed from time to time. Some buoys moved toward the east 10° in longitude in only two weeks, but sometimes it took several months. Figure 4 shows the trajectory of a buoy that was captured in an eddy for nearly six months.

Our estimate of the final destination of the waste materials was the east side of the Hawaiian

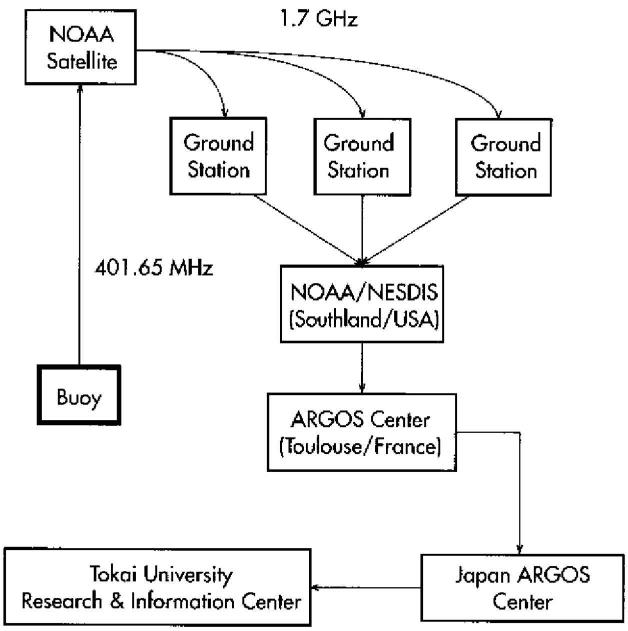


Figure 2. Information flow in the ARGOS System.

Islands. Unfortunately, due to battery limitation, most of the buoys stopped transmitting signals by the end of April, before reaching the final destination. The drifting speed of the buoys was much slower than we expected.

In the beginning of June 1993, we released a number of new buoys with stronger batteries in the Kuroshio Current near Japan. Figure 5 shows the overall trajectories of these buoys through the end of August 1993. We hope that these buoys will guide us to the final destination.

SATELLITE IMAGE ANALYSIS

Sea surface temperature images from NOAA and GMS show a clear pattern and a wide view of ocean currents. In order to compare the trajectories of buoys with the sea surface temperature pattern shown in satellite images, the trajectories were overlaid on satellite images.

Usually, the Kuroshio Current flows along the southeast coast of Japan. However, sometimes the

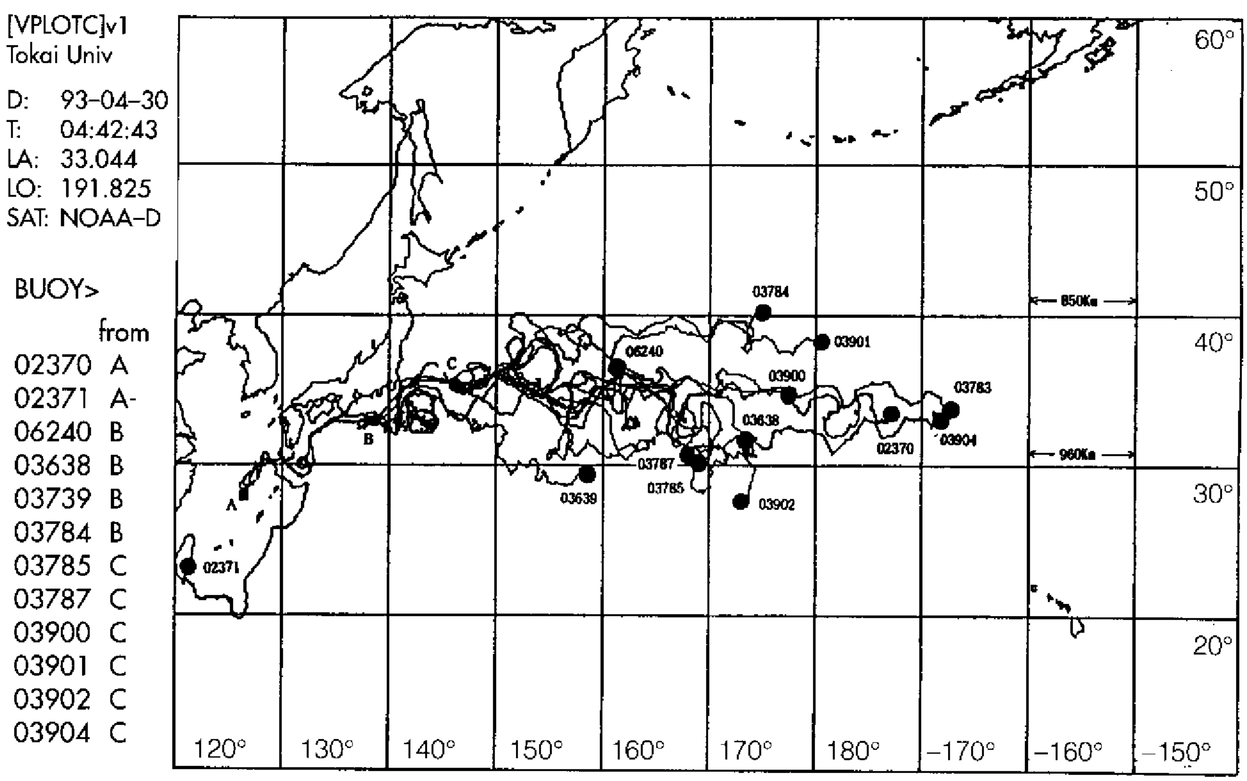


Figure 3. Trajectories of the buoys for the first stage (October 1992–May 1993).

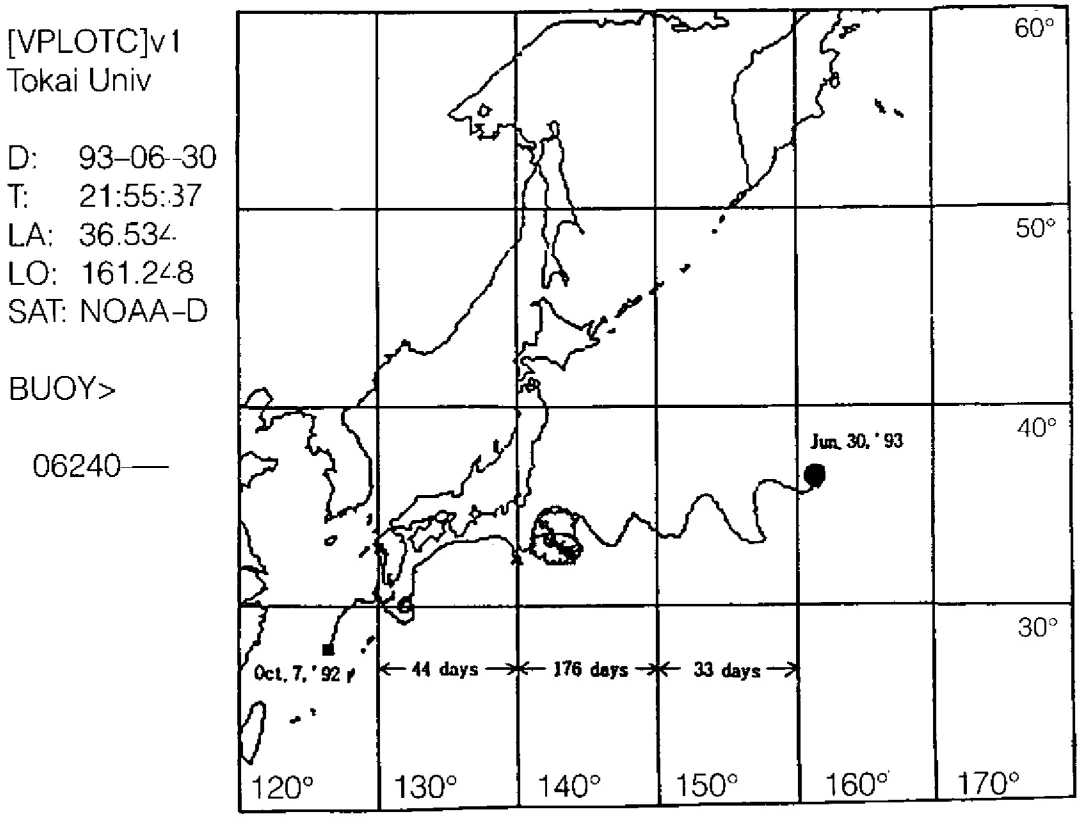


Figure 4. A buoy captured in a local eddy.

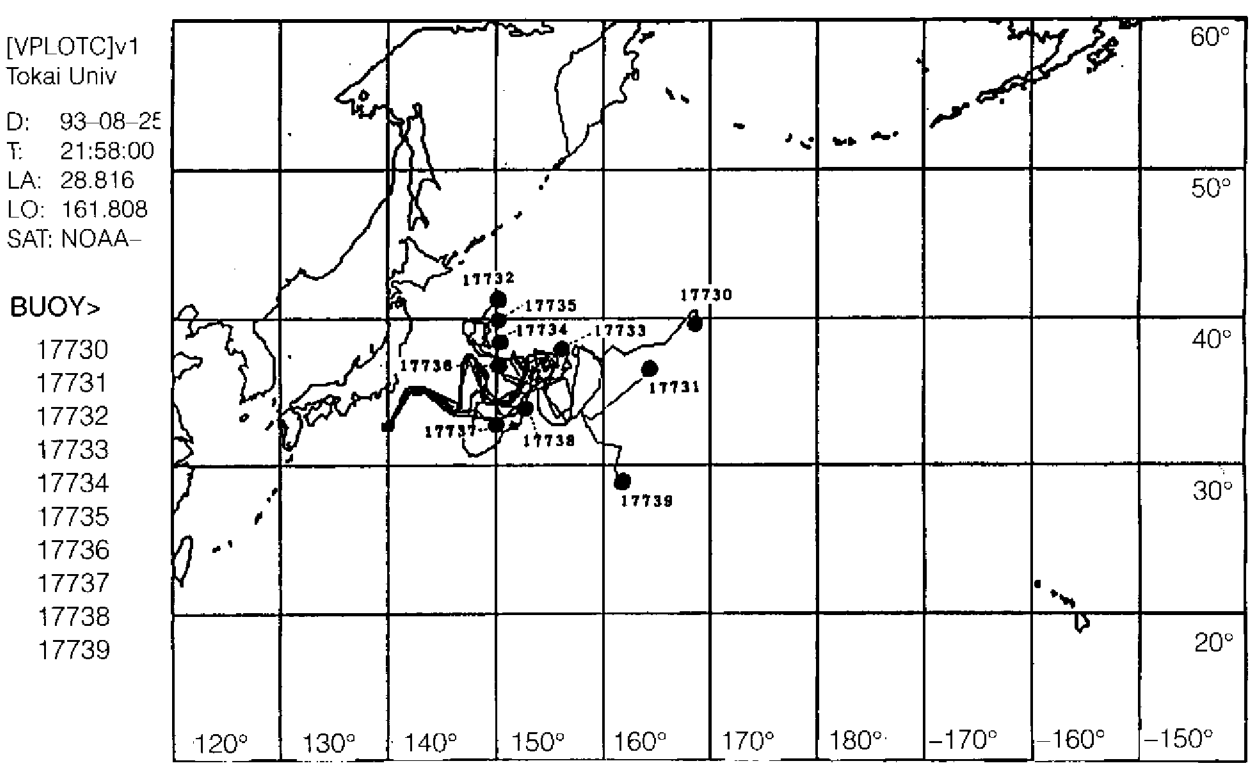


Figure 5. Trajectories of the buoys for the second stage. (June 1993–August 1993).

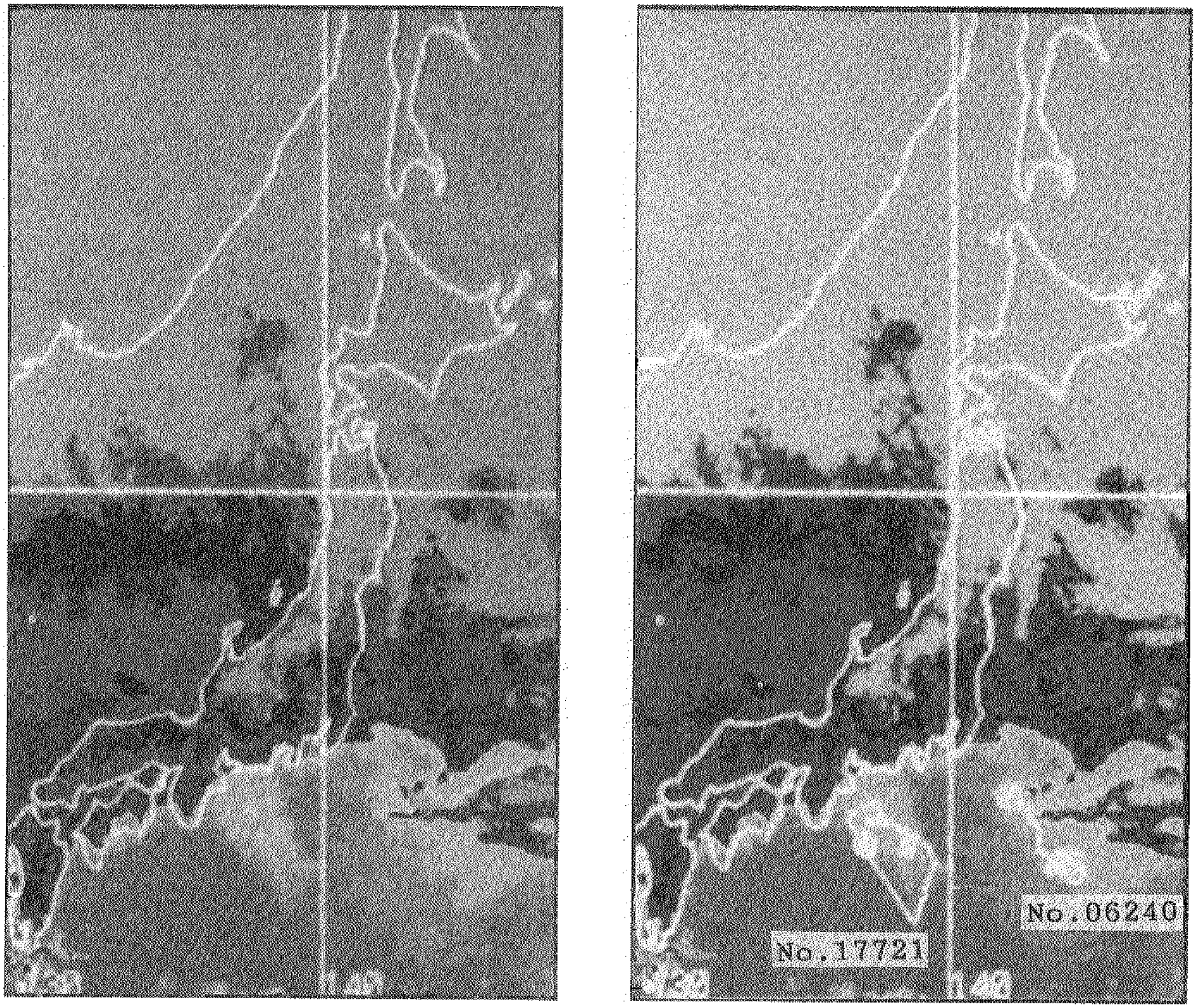


Figure 6. Trajectories overlaid on a GMS thermal image. Left: GMS image (April 19, 1993); right: Buoy trajectory (April 5–May 5, 1993).

Kuroshio Current forms a large eddy toward the south. On April 19, 1993, such an eddy was clearly captured by GMS. Figure 6 shows one month trajectories of two buoys overlaid on the GMS image. The image clearly shows that one buoy (No. 17721) was captured in an eddy of the Kuroshio Current, and the other bouy (No. 06240) was drifting along the sea surface temperature boundary area. This example suggested to us the advantage of combining satellite images with buoy trajectories.

There are two major problems when comparing the trajectories with satellite images. One is the time scale difference between the two data. The trajectories are the results of a several-month drift of buoys, while a satellite image shows the ocean current pattern at the moment of observation. Another problem is that it is very difficult to find cloud-free satellite images. Clouds in the image prevent analysis. Our next step is to perform multitemporal satellite image analysis.

CONCLUSION

Due to their battery limitation, the buoys of the first stage deployment did not show the final destination of waste materials in the North Pacific Ocean. However, the trajectories of the buoys provided information on the complex sea current phenomena in the North Pacific Ocean. The overlay of trajectories on the satellite images suggested to us the importance of using satellite images for understanding the mechanism of buoy drift caused by the complex sea current.

We hope that our second stage of buoy deployment will guide us to the final destination, and that the data acquired through this project will assist us in tracing the flow of debris and waste materials in the Kuroshio Current. Ultimately, we hope the results of our Marine Environment Project will contribute to the preservation of the health of the North Pacific Ocean.

The Difficulty of Enforcing Environmental Protection Legislation

Vladimir Kurilov
President, Far Eastern State University
Vladivostock, Russia

My specialty is law; therefore I would like to discuss the legal problems of environmental protection in the Pacific region.

Activities dealing with environmental issues in the Asian and Pacific region are numerous and intensive. All of them show that a serious threat of ecological disaster is looming over the region. Quick and effective measures must be taken to avoid such a catastrophe. The urgency of this matter was stressed at the Third Asian Pacific University Presidents Conference held in Vladivostok in August of 1991. I'm sure that this fourth conference will come to the same conclusion.

One of the ways to slow—and eventually reverse—the destructive processes in the natural environment is to direct the world public, as well as all national governments, to the materials of our conference. On the other hand, on their own, neither such activities nor the realization of the threat of the imminent environmental disaster can stop these destructive processes or even slow them. Nor can these processes be reversed simply by finding the reasons and major factors of pollution and environmental degeneration. The solution to environmental problems can only be found in clearly defined and well-coordinated activities of all countries, their governments, and individual industrial enterprises, farms, and companies. To control and coordinate activities directed toward the protection of the environment, certain rights and responsibilities should be bestowed on the participants. That means the relations between countries, governments, government agencies, and enterprises should be regulated by law.

On a global scale, the legal regulation of environmental protection is carried out on two levels—through national legislation and through international law. The Russian Federation has very powerful legislation on nature protection. All the environmental protection activities in the country are controlled and coordinated by the Ministry of the Protection of the Environment and Natural Resources and the federal agency of Meteorology and Environment Monitoring, as well as some other ministries and agencies.

On the regional level, these functions are carried out by the local nature protection committees. These committees have their own budgets and are authorized to enforce the implementation of environmental protection requirements by local enterprises and companies. According to labor, administrative, and criminal law currently in force in Russia, there are various penalties for state officials, enterprise managers, and individual citizens who fail to abide by environmental protection legislation.

The United States, Japan, and other countries have similar legislation. However, at least two factors hinder the enforcement of environmental protection legislation. First, the military-industrial complex encourages governments to close their eyes on breaches of environmental protection legislation. Second, the world ocean and atmosphere are regulated by international law, and hence are beyond national jurisdictions. The world community can do little to influence the adoption or the enforcement of national environmental protection legislation. Consequently, international law is extremely important in protecting the environment. Its priority over national legislation is recognized by many countries. The special role of international law in the sphere of environmental protection is also due to the global character of nature itself.

If all the above is true, we come to the conclusion that it is an urgent necessity to prepare and sign an international convention on environmental protection in the Pacific region. Its preparation must include several steps. First, scientific research and investigating environmental issues, identifying the most urgent, as well as finding the scientific and technological tools to deal with those issues; second, working out the legal aspect of the convention; third, dealing with the political aspects of the convention—finding ways to involve the United Nations and the countries of the region. Fourth, conducting an initial conference that would result in signing the convention.

The esteemed participants of this conference have done very much for the investigation of environmental issues in the Asian-Pacific region. Perhaps, on the basis of our conference, we could consider establishing an international scientific council on the research and monitoring of the environment in the Asian-Pacific region. We could invite representatives of government agencies to cooperate with this council. This council could assume responsibility for carrying out scientific research and investigation of the primary issues, thereby laying the foundation for an international agreement on collective environmental protection of the Asian-Pacific region.

The human race is getting perilously close to the collapse of ecosystems. To avert ecological catastrophe, the collective action of countries and governments is needed; setting up an international system of collective environmental security is necessary. The establishment of such a system is a moral responsibility of scientists and political leaders all over the world. Thank you.

The Role of Data Interpretation

Kent W. Bridges
University of Hawaii at Manoa
Honolulu, Hawaii, USA

INTRODUCTION

I have a "good news, bad news" message to bring to you today.

The good news is that the technology to take the data interpretation process into the future has arrived. Most scientists have easy access to the computational power needed to do analyses, interpret complex results, and prepare sophisticated displays of the results. Communication networks that let us share data and interpretations quickly are also in place.

The bad news is that we are not really prepared to use this technological capability. We have massive infrastructure barriers that must be changed if we are to keep up with the demands of using information to solve regional environmental problems.

I've not come to present you with a comfortable vision of the future. My mission is to confront you with some difficult challenges. These are not going to be technological challenges. Rather, they focus on getting our institutions to promote the widespread use of existing technology.

I want to present this message in three steps:

- First, I'll describe the process of data interpretation as it is now performed by enviromentally oriented scientists.
- Then I'll describe the inertia that keeps us locked in the past and hinders our responding to new demands.
- Finally I'll cover some aspects of institutional structure that compound this problem.

I expect to leave you with the impression that something needs to be done and that we are in a position to make some changes.

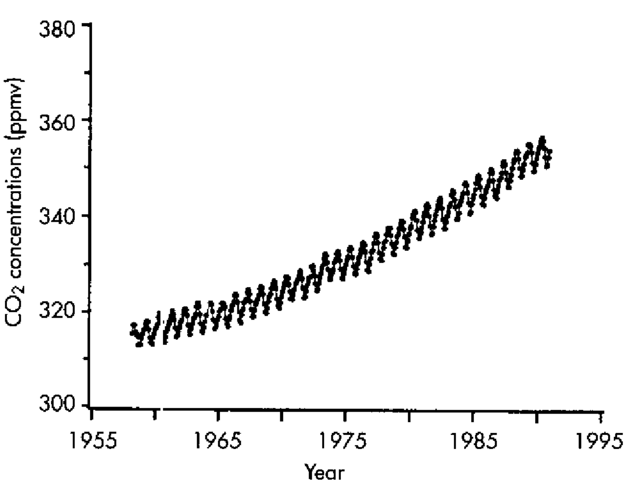


Figure 1. Monthly atmospheric CO_2 concentrations at Mauna Loa, Hawaii from 1959 to 1990. (Boden et al., 1992)

THE PROCESS OF DATA INTERPRETATION

Collecting information about a problem, such as a specific case of pollution, is not enough. Data values must be interpreted for them to become useful. Sometimes the interpretation is done quite easily. An example is the CO_2 trend that was detected at the Mauna Loa Observatory in Hawaii. This high mountain turned out to be an ideal monitoring site and consistent records were taken for several decades. When plotted, as in Figure 1, the interpretation is quite clear.

The plot of CO_2 against time, showing an annual cycle and long-term upward trend, is such a clear demonstration of a major environmental problem that it has been reproduced many times. This has gotten the attention of scientists, decision makers, and even the public throughout the entire planet. It has provided not only the impetus for worldwide action, but it also shows us a way to monitor whether our actions are effective. This example demonstrates the process of data interpretation working at its best.

It is rare for us to have such a straightforward data interpretation process. I'll use the Mauna Loa CO_2 data as a reference to highlight some of the problems. The Mauna Loa data were collected at one place. More often, we need to do sampling in many places. It is beyond the scope of this presentation to discuss the data collection concerns of site selection, measurement standardization, and instrument intercalibration. In terms of difficulties in the interpretation process, I will point out there are difficult problems in how spatial data will be analyzed, including interpolation and display.

The Mauna Loa data consist of a simple, easily understood environmental parameter. For most of our problems, it isn't always clear what we should be measuring. Frequently, we need to measure many things. Our environmental assessments generally involve multiple factors, some of which may be quite abstract. Not all of the factors are quantitative. Combining all the data into a meaningful synthesis is a challenge. The Mauna Loa data were presented in a very traditional chart (Figure 1). This presents no interpretation difficulties. Our more complex problems don't have such clear presentation models.

To imagine the data interpretation difficulties, you might want to think about the problems of coral decline. Here we have a significant problem that occurs over large areas. The trends are not particularly clear. We are quite sure that a number of factors are responsible for the death of corals, but we have made little headway in presenting a clear, understandable picture of the overall process. The coral decline process is typical of the many data-interpretation situations in which we find ourselves.

The Purpose of Data Analysis and Interpretation

The purpose of data analysis and interpretation is to communicate. It is a process that generally involves four stages:

- *Data organization*: Data values are put into a unified format.
- *Data reduction*: An analysis process is applied that reduces the observations to fewer values.
- *Data presentation*: The simplified set of values is displayed in a standard format.
- *Data evaluation*: Often, this is linked to a system of decision making.

The techniques to do this are well supported by computer technology. Off-the-shelf software can be used to assist many of these tasks. I don't mean to imply that data analysis and interpretation are easy. It has been my experience, watching typical researchers, that it takes just about as long for most people to finish the data analysis and interpretation process as they spent collecting the data itself.

Metaphors

Metaphor is a key concept in the process of analyzing data. In this context, a metaphor is simply a mental image that brings in a rich set of collateral information. If I say "African savanna," I mentally picture a complex set of information. My mental image includes a grassland with scattered trees. It is rich with mammals. It has an interesting set of invertebrates. Most people who are interested in the environment share this mental picture, at least in broad outline. That is the value of a metaphor. We communicate large amounts of shared perception through the use of metaphors. For example, the Mauna Loa CO_2 trend has become a metaphor for the direction and rate of climate change.

A large part of the scientific enterprise involves the creation of metaphors. They are fundamental vehicles with which we communicate. Metaphors are also used as general models against which new experiences are judged. It is when we have a conflict between a metaphor and new observations that we bring in our critical analytical skills.

My favorite example of the scientific use of metaphors is a story about Charles Darwin (Wallace et al., 1981). Let me give it to you in a brief form. Picture Darwin near the tip of South America. He is standing in a rolling grassland, viewing the landscape. To Darwin, this was metaphorical English countryside. The plants were about the same, as was the weather. As Darwin checked what he was seeing against his metaphorical image of the English countryside, he was struck by something that was missing. There were no rabbits. It was this lack, the incompleteness of what he was seeing, that got Darwin thinking. Why were there no rabbits? This question was to lead him to his explanation of evolutionary processes. My point is that a well developed set of metaphors builds the basis for separating the expected from the unusual. When our metaphorical model fails us, we can't help but seek an explanation.

Data analysis and interpretation deal with the development and use of metaphors. I believe that we have relatively few general structures into which we fit data. Remember that the process of data analysis involves simplifying a complex set of data into a form which can be more easily understood and communicated. Probably the most frequently used simplification model is the normal curve. The adoption of this particular statistical distribution serves as a good example of how we develop metaphorical tools not only for analysis, but also for communication.

A century ago, researchers didn't use just the normal curve as a way to describe the statistical distribution of many common phenomena. There was, in fact, a hotly contested rivalry between several similarly shaped distributions. For several years, researchers fit data to the competing models until it was finally decided that the normal curve generally worked better than the competing mathematical distributions. Note that these scientists were not uncovering some "correct" universal relationship. What they were finding was a relationship that was most generally useful. Once the normal curve was seen as the "winner," it could become a metaphor. Researchers would not have to try analysis alternatives. They could easily communicate a summary of their measurements by referring to the parameters of the equation on which this curve is based.

Imagine what would happen if I decided that my data were better described by a slightly different equation. If I used it as a way to communicate the results of my study, would I be understood? Probably not, especially if this were an obscure equation. Scientists have little time to explore new means of expression. They would not have any way to put my values in context. My work would be outside the bounds of their experience. They wouldn't have a metaphor with which to make a comparison.

I can demonstrate this problem of violating a basic metaphor with an experience that I had once while reviewing a manuscript. There is a fundamental relationship in vegetation ecology in which the number of species in small areas is compared to increasingly larger areas. Small areas have few species. Larger areas have more species, but up to some limit. Eventually, if you were to analyze an even larger-sized area, it would be unlikely that you would find any more species than a slightly smaller one. Vegetation ecologists use this relationship to determine the minimum area to be sampled. The relationship is portrayed graphically in a standardized way. To an experienced researcher, considerable information can be obtained by just glancing at such a plot.

The paper that I was reviewing contained a plot with the axes reversed. Even though the information was the same, I couldn't understand what was being shown until I replotted the relationship. The metaphor had been violated with the result that I failed to appreciate someone else's study. We rarely have either the time or motivation to do as I did by recasting data into a familiar representation. It was difficult enough with this simple case of swapped axes. Imagine the difficulties when you are shown a truly innovative new form of data presentation.

The conclusion is that scientists are very conservative in the development of new ways to communicate information. A new way implies that the presentation doesn't correspond to a familiar metaphor. Most scientists don't need to develop new metaphors. We probably have an adequate set of communication metaphors for most scientific problems. These are well entrenched. For example, many of our most familiar graphical metaphors extend back more than 200 years. One person, William Playfair, is credited with devising the time-based trend plot, the histogram, and the pie chart (Tufte, 1983). Charles Darwin, about a century later, provided a tree-like diagram that has led to our more abstract phylogenetic diagrams. The question is open, however, about whether we need new metaphors for some specific kinds of research.

TWO APPROACHES TO SCIENCE: ANALYSIS VERSUS SYNTHESIS

There are generally two approaches to doing science. One is the reductionist approach. The other involves synthesis. Most scientific research is highly reductionist. We take problems apart and investigate them in greater and greater detail. In contrast, there is much less emphasis on the alternative scientific process, that of synthesis. In synthesis, we look in the opposite direction and search for the emergent properties as we aggregate information.

Most of our data interpretation strategies are heavily biased toward reduction problems. This seems appropriate since scientific research in general is heavily biased toward reductionism. We make scientific progress on problems by dividing the problem into smaller units and investigating these. However, we should recognize that pressing environmental problems involve the synthesis of information. What is needed are techniques that will encourage synthesis.

Recent History of Synthesis Studies

There are a few good examples of explicit attempts to improve our ability to synthesize environmental information. In the 1970s, the International Biological Program (IBP) attempted to foster synthesis-oriented research. Most of the studies were at the biome level of organization and involved dozens to hundreds of researchers in each study. Examples of U.S. programs include the Grasslands Biome, the Desert Biome, and the Deciduous Forest Biome.

The interpretation strategy in the IBP biome studies was to build mathematical models of the processes occurring in these biomes. By simulating the population processes of all the organisms, the models attempted to predict the dynamics of the systems at future times. What the IBP studies were trying to do was to create a new analysis metaphor that would greatly increase the rate at which we could understand ecological systems. We wanted a breakthrough so that we could accelerate what had been an incremental acquisition of understanding.

Modeling and simulation make an elegant approach. If they work, it should be possible to manipulate the models to find out new things, such as how the system will perform if a key animal species is eliminated. It certainly held the promise of accelerating our understanding. The results of about a decade of intensive research produced a lot of written materials about the biomes under study. Indeed, we gained considerable insight into how these systems operate. But my personal view is that the models were not widely understood. While they may have been successful, they didn't enhance communication among the participating scientists. Few researchers were willing to learn the mathematics and computer programming required to fully participate in the modeling process. As a result, I believe that we got linear progress, but not the breakthrough we wanted.

Change in Paradigm

I'd like to explore the intent of the International Biological Program for a moment. It was started during a time of rapidly increasing environmental concern. Past research had been giving us incremental increases in our understanding. The IBP was an attempt to change the basic shape of this chart. We expected a dramatic increase in efficiency by doing something fundamentally new.

We have a name for this general process of fundamental change. It is called a change in paradigm (or paradigm shift). We are doing something in a substantially different way. The result is that we get a new level of performance and, we hope, an increased level of efficiency. Paradigm shifts are not new and they certainly are not limited to environmental studies. I'm going to give you some examples of changed paradigms so that you can get a better feel of how we react when we encounter them. I hope that by doing this, you will see that if we are to be successful in changing our interpretation paradigms in environmental studies, we had better be prepared for some of the consequences.

The first typewriters were not accepted. They were seen as an attempt to replace handwriting. At the time, people took great pride in their handwriting. The typewriter removed the pride that came with this skill. It took quite a few years for people to recognize that the typewriter had a different purpose.

The early movies were filmed versions of stage plays. It took a while for movie makers to realize that they should get the camera out of an audience member's seat and get it involved in the action. Once the mobile camera was accepted, stage plays and movies became fundamentally different entities.

Computers were first seen as calculators. It has taken many years to show that computers have a much wider role. In fact, the calculation capability of computers is, for many people, a rather insignificant part of their use.

The airline industry has gone through a sizable paradigm shift. The small changes include the increased speed and carrying capacity of planes, advanced avionics controls that reduce the need for a pilot to fly the plane, and the whole system of ground control. Even airline reservation systems have made a fundamental difference. We no longer are stacked for hours above an airport waiting to land. The point is that there have been many events in the development of the airline industry that has changed its fundamental character. Viewed individually, they were not dramatic discontinuities. Together, they have been revolutionary; the result is a true change in paradigm.

Four characteristics of changes in paradigm emerge from these examples.

- Paradigm change is generally technology driven.
- Substantial paradigm change often requires many developments—not just one.
- Some uses of technologies that seem to have little to do with the situation (e.g., information technology helps the aviation industry).

- People involved have to accept handling situations in radically new ways.

An important point about changes of paradigm is that we seek them out. We consider them important. Can we create a change in paradigm as we cooperate in trying to understand and protect the environments in the Pacific Basin?

New Interpretation Possibilities

As we have seen, changes in paradigm often involve new technology. What are the candidates? We have a wealth of new information storage and exchange technologies available to us. Among these are:

- Machine readable collections. We now have digitally stored atlases, encyclopedias, handbooks, and monographs.
- New forms of information presentation, including new formats for storing still-color pictures, digital video, and digital audio. New formats, such as animations, hypertext links, and virtual reality are increasingly practical.
- Networks connecting computers have grown so rapidly, it is not clear how many are connected. By any measure, the electronically connected community of scientists is very large. In the U.S., "information superhighway" has become a popular metaphor which underscores the place of digital technology in mass communication.

The technologies themselves are not the central concern. What they provide is a potential to change our data interpretation paradigms. Let me give you a few small examples. Then I'll try to synthesize this into a more comprehensize framework. Hawaii's terrestrial ecologists have gotten a new handbook of flora from the taxonomists. It is a very traditional book. All of the illustrations are line drawings. It simply would not have been practical to add color photographs. Now, however, we have CD ROM (compact disc read-only memory) capabilities. For an additional several dollars, thousands of photographs can be distributed.

Computer graphics have made it relatively simple to create more expressive means of data display. We can now use clip art maps and add color for emphasis. We can quite easily explore the modification of traditional display designs to see if we can enhance communication. The new "information highways," such as Internet, are a decentralized way for us to provide each other with information; they fundamentally change the way we distribute information.

DISCIPLINARY INERTIA

Even though these technologies have considerable promise, they fall outside the traditional ways in which our scientific disciplines work. Information that is not bound into a book doesn't count as a publication. Colorful charts that have an innovative design are not published in scientific journals. Databases that are made available on a computer network are not recognized on a faculty member's vita. Put simply, disciplines discourage innovation in areas that I believe are vital to investigating environmental problems aimed at the synthesis of information.

A Naturalist Metaphor as a Basis for Information Synthesis

I want to explore the possibility that we need more synthesis metaphors. In doing so, I recall a particular group of scientists who were good at synthesis. These scientists had an immense knowledge of the field situation. They were able to organize the bits and pieces and get a unified view of a complex situation. They were the great naturalists. What we need today are methods that will let us do the same thing. We need to handle more information in comprehensive ways. I propose that we look carefully at ways we can emulate the great naturalists of the last century. We need a naturalist metaphor. I call this the Naturalist Model.

Some of the characteristic features of naturalists point out things we need to regain if we are to do synthesis-level interpretation. I think this may give us some hints about how to overcome the disciplinary inertia that has inhibited the use of technological innovation. I want to focus on the "old time" naturalists. Most of these naturalists had similar characteristics, such as: possessing extensive libraries, maintaining a wide and varied correspondence, investing tremendous amounts of time in the field, often traveling to distant lands, and more recently, building a huge collection of photographs.

I'm not proposing that we do a *strict* emulation of past naturalists. Institutional policies, if not their budgets, rule out such a possibility. Imagine a young Charles Darwin applying for an assistant professorship in one of our institutions. Among his employment demands would be a request for a five-year absence while he did some field work. Also, the institution should not expect him to publish his results for at least 17 years after his return. We need to see what paradigm changes we can bring to a modern natural history researcher through the introduction of technology in other fields. What is the data interpretation armamentarium that we can supply with modern technology?

The Library

My institution's budget for its library is not keeping up with the demand. Not only are we unable to maintain our acquistion of serials, we have run out of space in which to store our collection. Any requests that I might make for expanding our holdings will not receive a particularly favorable reception. Instead, we are having to turn to the "just-in-time" delivery of information. This concept is not at all like the old interlibrary loan system. Now, organizations like the Colorado Alliance of Research Libraries (CARL) are having journals scanned and stored on-line. Requests for articles can be handled by networked computers. Currently, I can receive the paper that I need by fax. If the article is one that is already stored on-line, I can receive it in less than two hours.

There is, of course, some cost for this service; however, a thorough analysis of the current article-retrieval system might show that it is not as expensive as it first appears. What happens institutionally, however, is that the costs get shifted to new budgets—and it is important that budget reallocations within an insititution reflect these changing relationships. Administrators will recognize the difficulty of reallocating budgets.

The industrial sector of modern society is coming to depend on "just-in-time" delivery. They have found an immense savings in storage costs, increased competition between suppliers, and an ability to modify their products in a shorter time. These sound like the sorts of things that academic researchers need, too. A side benefit of a "just-in-time" information delivery system is that an institution's library holdings become less critical. Ideally, a researcher in a small institution has the same access to information as one in an institution with a great library. Researchers who live in relatively remote places may be able to get information as easily as those in large urban centers.

The Correspondence

The means by which we correspond is changing rapidly. Electronic mail (e-mail), is spreading rapidly. This makes correspondence faster and easier. The relative informality of e-mail promotes information sharing that is important, but which often is not included in more formal written correspondence. Most of us use e-mail for the exchange of text messages. Our systems are capable of much more. We can exchange computer-readable files. I can send you data that you can run through your analysis system. I can send you high-resolution pictures that you can view on your desktop computer, record on film as slides, enlarge as color copies, or put as images on videotape.

Several points are important. We have added efficiency to the communication process. We have made it much faster. We have reduced overall costs. We can distribute information that previously would not have been practical. Viewed in the perspective of the naturalist, it is clear that our modern e-mail systems give us unprecedented ability to communicate. The ease with which we can send messages to several people, our ability to forward messages to other people, and even the fact that we can store our messages and retrieve them at a later date, promise a communication system that can tie us together very effectively. Our institutions need to promote the use of electronic mail. We need to educate ourselves so that we get the maximum benefit from this capability.

The Travel

There are very large differences between how open-ocean scientists and coastal scientists study problems. In the open ocean, travel is necessary to get data. Actually observing the water has little value. It is the information that comes back from the instruments that counts. In fact, it really isn't important for the scientist to take the measurements, as long as someone who is competent can do it. On land, observations are important. It is the hundreds of things you see that influence your understanding of the system under study. There are many site-oriented questions—how warm is the water, where is the nearest river, what is the tidal pattern, how clear is the water—that provide necessary information. You need to go to the place to get that information. The more places you have visited, the better you are at synthesizing such a mass of information.

Increasingly, we should be able to share a lot of this information, perhaps reducing the need to travel. I am thinking specifically about how we share information through seminars. In my department, we give talks about specific areas we have visited. These are illustrated with pictures. In this way, we share our experience. Unfortunately, my departmental colleagues are not always my best audience. Many of them have only a peripheral interest in my research problems. What I want to do is share my travel experiences with my peers in the same discipline. We hear each other's presentations at major meetings, but I want to be able to exchange information more frequently. The technology exists for us to record our presentations on CD ROM, complete with audio and a large collection of slides. With existing technology, presentations of an hour or more can be stored on a single disk. The quality of the recording is better than video. Best of all, we can build such recordings from our existing resources.

We can aim at having fully digital, stored presentations. These can be sent across the computer networks to anywhere they might be useful. For example, the Chinese scientists in Hainan are likely to find studies being done in Hawaii which are examining problems very similar to their own. We are utilizing a new medium that lets us capture some rich stories in the tradition of oral history. Perhaps by exchanging such stories we will have a partial substitute for having to travel to other places to learn about their situations, how they have been investigated, and the results of their research.

The Photographs

An extensive set of photographs is an essential part of recording environmental information. As I've just discussed, showing slides is a way that we communicate with each other. We use these pictures in the classroom and we show them in seminars. My department has more than 3,000 slides. This is a rare collection of pictures. Many of the individual plants that have been photographed no longer exist. We need to be very careful with this collection of slides. They are used only by the faculty, and then under quite closely controlled conditions. They are rarely loaned, for obvious fear of damage or loss. As a result, one of our most valuable resources has very restricted use. A new technology is available that consists of scanning slides and converting them to digital images stored on CD ROM. These are called photoCDs. The scanning resolution is about one-half that of the original film.

Converting the Botany Department's slide collection to CD ROM is expected to cost between $2,000 and $4,000. Once it is converted, we expect to be able to make digital duplicates for between three and thirty dollars, depending on whether we make 1,000 copies, or just a single one. This copy will have most of the entire collection, although the resolution of the copy will be limited to 640 x 480 pixel display. With the addition of a CD ROM drive to a personal computer (currently between $200 and $500), you will be able to use this disk. The same disk will hold text, sound, and the scanned images. This lets us do useful things like provide the pronunciation of the scientific names of all the organisms.

The point here is that individuals can build very large collections of useful illustrations at very low cost. The pictures will be more useful than current slide collections because they will have machine readable databases of descriptive information. They will not fade, mildew, or otherwise degrade.

INSTITUTIONAL CHALLENGES

Our institutions can do many things to support innovative approaches to data interpretation.

Institutional Collaboration

If we have a common interest in the data, and we share in its interpretation, we are likely to obtain information that is much more meaningful. This is not a simple process.

Identifying Institutional Collaborators

My most valuable colleagues are likely to be those who are working on similar problems at other institutions. They are the ones with whom I want to communicate frequently and intensively.

We need to make sure that our institutions actively publish information about their researchers, their research programs, and their resources. This is best accomplished by publishing over the computer networks. Notice how this differs from our past practice. Before, we compiled our directories and sent them out to people who we thought might want to know. We were the active agents. Now, we compile such a directory and put it where people who are interested can find it. Those who want the information are the active agents.

Once I identify an appropriate person, all I need is an e-mail address. The institutional infrastructure exists that will allow many of the Pacific Basin universities to collaborate closely. We have linked many of our computers. What is lacking is that we don't yet know each other well enough. We have the network but we are not yet networking.

Review Academic Evaluation Criteria

There are strong institutional barriers to the use of new technology and innovative means of collaboration. I feel quite strongly that the academic evaluation system, for example, discourages innovation that leads to synthesis. Let me give you a few examples. Academic evaluation is primarily based on a faculty member's publication record. Yet by using the technology that I've been associating with a change in paradigm, you can't publish your results in traditional journals. Therefore, measures of academic impact—such as citation index scores—do not reflect what might be the actual impact of your research.

I'm doing two sorts of research in my laboratory investigating new ways of interpreting data. One involves the creation of animated 3D maps. In one project, I'm looking at the long-term pattern of rainfall over a complex landscape. The product is an animated projection of the rainfall contours on a 3D relief surface. This surface is rotated to different views so you can get different perspectives. Traditional publications can't be accompanied by a video. Representing this as a few still, black and white images in a traditional publication is so misleading that it has little value. Another project converts DNA data to music so you can try to find patterns by listening. Here, too, the results cannot be published in any conventional journal.

We have to be very careful that we don't accidentally inhibit innovation by relying exclusively on traditional evaluative criteria.

Try Joint Projects

We need to do some specific things to get started. Examples include:

- Provide e-mail accounts to anyone who wants to get involved, including students.
- Create Gopher information servers to inform others about your institution, its staff, and its research. (Gopher is one of several tools that allow Internet users to search data files distributed over the network.)
- Experiment with exchanging video presentations as a prelude to doing more advanced digital presentations.
- Reallocate budgets to allow pilot projects that use fax information delivery as an alternative to libraries.
- Convert key collections of slides to photoCD so they can be distributed.

CONCLUSION

As long as it is an airline pilot's responsibility to fly the plane, we are stuck with the status quo. We know that with current technology, computers can fly planes. Often, they do it better than humans. We also know that some military planes can not be flown by humans; they must be adjusted with the speed and precision that is only possible with computer control. The change in paradigm requires that the pilot become a system manager. It takes human judgment to oversee the entire system. It takes a different set of skills for this new job. This analogy re-emphasizes how a paradigm shift affects us.

As scientists, we must also take on new roles. We must be prepared to contribute in new ways. We must be prepared to be evaluated with new standards.

REFERENCES

Boden, T.A., R.J. Sepanski, and F.W. Stoss (Eds.). 1992. Trends '91: A compendium of data on global change. Carbon Dioxide Information Analysis Center, Oak Ridge, TN.

Tufte, E. 1983. The visual display of quantitative information. Graphics Press, Cheshire, CT.

Wallace, R.A., J.L. King, and G. P. Sanders. 1981. Biology, the science of life. Scott, Foresman & Co., Glenview, IL.

Open Ecological University: One Approach to a Modern Environmental Education

Valery Petrosyan
Moscow State University
Moscow, Russia

During many years of involvement in environmental studies and teaching at Moscow State University, I have been trying to understand the best way to bring young people modern environmental knowledge. It was not very easy to reach final conclusions because the more concern was rising around the world about environmental issues, the more deeply people would need to be involved in environmental education. In various countries, there are many different approaches to teaching students—how to teach young people, how to teach the general public, how to teach decision-making people about environmental issues. All of you, being involved in environmental problems, have realized in your own experience that this is not a very easy problem to solve.

In my country, environmental issues are a subject of very great concern. Today, quite a few people around the world are talking about serious environmental problems in Russia. I would like to tell you a little bit about environmental problems as we see them, and particularly how I see them as a chemist.

I have several duties in my country. I am Vice Chairman of the Supreme Ecological Council of Russian Federation, which is a scientific and consulting body for the Russian Parliament. Seventy-five people who work in various fields of the environmental sciences consult the Committee for Environment—which is a part of Russian Parliament—on how to deal with the environmental problems we have in our country. I also head the chemical safety section within the Ministry for Environment of the Russian Federation. Chemical safety is one of the areas where complex approaches must be used. In studying problems of chemical safety, it is not enough to get quantitative data on the content of harmful chemicals in the environment. It is also important to understand the toxicological properties of these chemicals and how they are affecting the health of the environment and of humans. This example shows the advantage of teaching both young people and specialists the complex approach.

ENVIRONMENTAL CONCERNS IN RUSSIA

Environmental problems can only be understood in reference to their economic context. The Russian economy is not in very good shape today. Production is going down. The main factors that were affecting the economy last year were the failure of the political administrative structures of the former USSR and also the long-standing negative tendencies in economics of the former USSR. But that's the bad news. The good news is that because of radical reforms, we do have new processes in Russian economics, which act in a positive way. Quite a few people, especially young people, benefit from these reforms.

The general volume of production in 1992 was 18.8% less than 1991, and two of the fields—metallurgy and chemical industry—had even sharper declines. In metallurgy, production was 26.8% less, and in the chemical industry, 22.3% less. From the viewpoint of environmental problems, it was unfortunate to see that the release of harmful chemicals to the atmosphere, for example, was only 10% less last year, and there was no decrease in the volume of waste waters. The question is why, if production is decreasing to such a great extent, the releases into the atmosphere and the natural waters are not decreasing correspondingly.

The answer to that question is simple but very sad. Old equipment and technologies are used in most of the regions of Russia. I have been heading the governmental expertise in one of the most important industrial areas in Siberia—Kuzbass. Kuzbass is highly industrialized, with a working population of 3.2 million people. This is the place where Russia gets ores and coal, and produces metal. The environmental situation there is very bad. The head of this region, Mr. Tuleev, wanted to declare the Kuzbass area a region of environmental emergency.

But a new law for environmental protection in our country was issued a year and a half ago. According to the 58th paragraph of this law, if the region is declared to be a zone of environmental emergency, you have to shut down all the plants and factories, all the businesses, that harm the environment. According to the data of our specialists, most of the plants and factories in Kuzbass would have to be shut down. If we did that, instead of an environmental crisis, we would have a social crisis, because the 3.2 million people who live there need to work.

Therefore, we could not agree with Mr. Tuleev's intentions. The proposal I submitted asked the government and President Yeltsin to give that area additional licenses and quotas to sell their products (ores, coal, and metals) to foreign countries, and not to tax the income from that. We asked the government to watch the situation very carefully and the money they received from the additional quotas would be spent to build new cleaning devices and buy new technologies. At first Mr. Tuleev didn't agree with this proposal, but we explained that it was the only way. Now he believes that was the best decision for the region.

This example illustrates that decision-making people have to be environmentally educated; they have to have the appropriate level of what we call environmental culture. Of course, it is not easy to know all environmental problems in detail because most of the regions we are talking about have severe problems with the quality of air and with the quality of the drinking water, which I will discuss briefly.

Air Pollution

Let's have a look, first of all, at the quality of the atmosphere. As I have already mentioned, the situation is not very good because of the releases of harmful chemicals. For most industrial areas, the releases will be higher from the stationary resources, but in large cities like Moscow, St. Petersburg, Novosibirsk, and some others, most of the chemical pollution of the atmosphere comes from automobiles. For example, in Moscow it's about 85%.

Moscow's leaders do not even understand why there is such a high level of pollution in the atmosphere of their city. I was recently invited to a meeting of the Moscow city government. They have been discussing the city's environmental situation. Moscow is the only city in the country that uses unleaded gasoline; the rest of the cities are still mostly using leaded gasoline. The pollution of soils and atmosphere with lead is quite high in many places. Of course you cannot use catalytic converters when you use leaded gasoline because tetraethyl lead and other lead compounds poison the platinum metal catalysts which are used to convert carbon monoxide to carbon dioxide. But I told the government of Moscow that Moscow is in a fortunate situation since it does not use leaded gasoline. So the next step is a local law that will tell people that it is obligatory that they use the catalysts with the cars they run in the city. But the catalysts are expensive. Again, the question is what do you think about the health of the environment in the places you live, what do you think about the health of the people? Since that meeting, the Moscow city government is thinking seriously about introducing a local law to use the catalysts to convert the CO to CO_2.

Water Pollution

Now we come to the problem of water resources in Russia. Many pollutants in natural waters come from waste waters of agriculture and industry. The most severe problems are found in large industrial cities situated on rivers.

Drinking water is generally prepared by treatment of surface water, which is taken from the same rivers where wastes are discharged. Last year I was on the urgent presidential group in the city of Ufa, in the Ural area. Ufa is situated in the estuary of the Belaya River (White River). Quite a few people in Ufa suffered from the bad quality of the drinking water. People from Ufa sent samples of their drinking water to various places, including California and France and some other countries, for analysis. They suspected that it might even contain polychlorinated dibenzodioxins and polychlorinated dibenzofurans. The data they supplied me with were very controversial; but there is cause for concern. So now, we have a special laboratory in Ufa to analyze the quality of the drinking water. This lab is equipped with modern gas chromatograph mass-spectrometers (GC-MS), high-resolution gas chromatographs, and high-efficiency liquid chromatographs.

The problem of environmental education, in this particular case, concerns the people who planned chlorinated pesticide production. They were not considering the consequences when they put 50% of the entire Russian production of chlorinated pesticides in one small area, and in three industrial cities—Ufa, Salavat, and Sterlitamak—where all of these chemical plants are situated. With the poor quality cleaning devices at those factories, and with the very poor quality of the waste water, there has been an accumulation of chlorinated pesticides in the White River for many years. Ufa, the largest city of the Bashkyria Republic, has suffered the most.

As environmental educators, we must teach people about what happens during the preparation of drinking water. In my laboratory at the Moscow State University, we have been working for the last five years with the Moscow City Council on the problem of drinking water. Using modern equipment, including GC-MS analysis, we found 153 organic compounds in Moscow's drinking water. Many of these are organo-chlorine compounds. All of the organo-chlorine compounds are not in the natural water that is the source of the drinking water—the organo-chlorine compounds occur only in the tap water. The question is: "If those are not anthropogenic compounds and you don't find them in the natural water that has been used to prepare the drinking water, where do they come from?" We know from basic chemistry that when we put chlorine into pure water, nothing besides HCl and HOCl is formed. The organo-chlorine compounds are formed from the interaction of molecular chlorine with organic matter found in natural water.

What is the organic matter in natural water? The first answer is that we put chlorine into natural water to kill the pathogens: microbes, viruses, bacteria. These pathogens are living organic polymers. What does it mean to kill pathogens? It means we perform chemical reactions between chlorine and living organic polymers, which means we extract small skeletons of carbons and we put chlorines on those skeletons. This is one of the reasons why we get all of these compounds.

But then the question is: "Besides living organic molecules, is there some nonliving organic matter?" The answer is yes. We know that there is dissolved organic matter in natural water and there should be an interaction of the molecular chlorine with that dissolved organic matter. We teach our students humus chemistry because the dissolved organic matter in water is called humus and consists of humic acids and fulvic acids.

In the frame of the program called the Open Ecological University, which I discuss later in this paper, we teach not only chemistry students, but also students who deal with economics, law, physics, geography, and other subjects related to environmental and human health. We know they do not understand chemical details when we teach them humus chemistry. We have to be simple but clear. Of course, the structures of humus molecules look like skyscrapers in New York to people who have no chemical background. But chemistry and biology students understand very well.

Because we have worked with marine and riverine humus, when we began looking for the chlorination of humus, we understood how to isolate humus samples from the natural water. We would perform the reactions of chlorine with marine and riverine humus to understand what organo-chlorine compounds are formed because of that interaction. That means we can predict in what particular circumstances and situations how many compounds and how much of them would be formed during the chlorination of the drinking water. Because of these detailed studies, we proposed to the Moscow City Council that they not use chlorination as they do now. Instead, we recommend they use ozonation to kill pathogens and to use mild chlorinating agents, like nitrogen chlorides, as the final step when the water is coming to the consumer from the station.

Some practical aspects appear from those studies. For example, performing the biotests, we could understand those aspects for organic pollutants, like polynuclear aromatics or heavy metals, which are the typical inorganic pollutants. Using typical biotests like *Chlorella vulgaris* or *Daphnia magna*, we could see that when you have enough humus in your water, the humus forms complexes with the organic and inorganic toxicants. This helps the situation because when the toxicants are complexed with the humus molecules their toxicity is reduced.

I'm not telling you the details; I'm just showing you that environmental problems are very difficult and scientists are the people who are responsible for the whole situation because lay people ask very simple pragmatic questions. They ask if the water we drink is safe enough to drink, and we must answer them. They don't understand and they don't care about complicated tables and graphs. They care only about the quality of the water, and they insist on simple answers. Lay people do not usually ask scientists. They ask the city mayor, the deputies they elected. Those people, unfortunately, cannot answer them. They lack an adequate level of environmental education. We have to teach them, so they will be able to answer simple and pragmatic questions.

Soil Pollution

Soil pollution in Russia is also an important issue. Since 1980—for the last ten years—we have used 150,000 tons of pesticides. Those are all kinds of pesticides, of course: organo-chlorine, organo-phosphorus, sulphur containing, nitrogen containing, triazines, and some others. People mostly use organo-chlorine pesticides like 2,4-D, 2,4,5-T which are the compounds responsible for the formation of dioxins and furans in the water of White River in the cities of Ufa, Sterlitamak, and Salavat.

I asked a director of a pesticides factory about the technologies used at the factory. He wasn't able to answer, so I went to the production people and asked them to show me the phenol they use to obtain the final products. Teaching students organic chemistry, we know that phenol itself is a pure white crystalline compound. Instead of seeing that beautiful white crystalline compound, I saw a brown, dark, dirty liquid, which they use for chlorination. Then I could tell the director what was happening; if you use that type of phenol you get everything, including highly toxic dioxins and furans.

So this is again a matter of the level of environmental education even when we are considering specialists who are responsible for production of particular products.

Disposal of Chemical Warfare Agents

The problem of chemical warfare is also an important subject. Two years ago, President Bush and President Gorbachev (at that time the president of the Soviet Union) signed an agreement about chemical warfare disarmament. This is a very difficult subject. It has been announced all over the world that 40,000 tons of chemical warfare agents are stored in Russia. Most of them are organophosphorous compounds, while 7,000 tons of them are an arsenic compound called lewisite. To destroy those 40,000 tons of chemical warfare agents is a big problem. They are trying to use the same factories where they produced the agents to destroy them. But people who live in those cities are against these projects. There was a case of an American delegation that came to the city of Chapayevsk to see a plant; but when the Greens in the city learned that an American delegation was coming, they feared that the delegation would endorse the project, so they came to the airport and said, "no way for you to come here, go back." The delegation flew back to Moscow and there was no chance for them to see that plant and the people opposed to disposal of chemical warfare agents in Chapayevsk.

OPEN ECOLOGICAL UNIVERSITY

Moscow State University has three types of environmental education. First of all, within the various departments such as physics, biology, chemistry, soil sciences, geography, geology, economics, and law, we have specialized chairs. The specialized chair of ecological economics was founded in 1979 by the late Academician Khatchaturov. They have very good people who understand ecological problems and who work very successfully in that field. People in physics and all the other departments also work on particular environmental problems. Because they teach students, because they have so-called diploma students who work for the degree of master of science, there is an environmental sciences specialization. Graduate students, of course, are doing their Ph.D.'s in various fields of modern environmental science.

Every year, 215 students get their master of science degrees in chemistry. Only eight, or at most ten, do their master of science thesis in the field of environmental chemistry. The same situation exists within the other departments. So what about the rest of the people? I mean, how can we graduate students who have no idea about the environmental sciences?

Quite a few people were worried about that and finally, three years ago, we founded the Open Ecological University. This is a two-year program. First-year students take 80 hours of classes. For students who pass the intermediate exam successfully, the second year includes seminars, labs, fields, computer simulations. Under the guidance of one of our professors, second-year students write a report on specific environmental issues and take a final examination. If they do all that, they get a special diploma which says they passed the two-year program of the Open Ecological University.

The third type of environmental education at Moscow State University is the specialized center which trains people—specialists—in the field of environmental sciences. People come from all over the country, sent by the businesses they work for. These businesses pay for their education. We have special rooms on campus for those people. Quite a few people come from Moscow, so they don't need the rooms, but we have at least a hundred rooms for the people who come from all over the country to be trained in the field of environmental science.

In 1990, we had only 67 people registered for the Open Ecological University program. The next year, the number of people increased sharply, up to 253. And last year we had 678 people registered. The program has become very popular in Moscow with the students of Moscow State University and other Moscow universities and institutions. They are not pushed to come; they come because they feel they need a modern environmental education. Of course, it is very important that this is free for them. I get the money from sponsors to pay my professors for the lectures and classes they offer.

I don't know how many students will be in the program this year, but we are optimistic. We care very much about the level of their knowledge after the first year at the intermediate examination. Then we see how well they do in the classes, fields, labs, and the specific project they write. The final examination is also quite difficult. In 1991, of 67 students, only 34 received the diploma. In 1992, of 253 students, only 118 students—less than 50%—got the diploma. The rest received a piece of paper saying that they participated in the program, but were not very successful. That makes a big difference for them because today the people who successfully completed the program are highly acknowledged within the country; they are invited to come to work within the Ministry for Environment, within the regional bodies responsible for environment, and other institutions.

As to the lecturers, we have very well-known scientists, such as the famous academicians Moiseev, Osipov, Zolotov, and others. The best professors of the University of Moscow give the lectures within the program. Students feel very good about the level of knowledge they get.

The 80-hour lecture course is divided into seven blocks. The first is environmental biology, which is general ecology. The second is geoecology, which includes both geographical and geological aspects. Environmental chemistry and toxicology are next. We finish with environmental chemistry the first semester, 40 hours. The second semester, we start with ecological economics. Then we give environmental legislation. This part is taught by Professor Petrov, the head of the Environmental Legislation Department within the Law Faculty of the University of Moscow, and the principal author of the state law for environment protection. We then have environmental expertise. This part is taught by the chief advisor for environmental expertise for our Minister for Environment. Dr. Burman is not from the University, but she is the best known specialist in the country in that field. Finally, we have global problems of the environment. This is taught by a very famous professor, Nikita Moiseev, who has written six or seven books about modern environmental problems. He's a great mathematician specializing in environmental modeling.

Briefly, that is the program. As I said, it has become very popular and now many universities around the country are asking us to help them create similar programs at various universities in Russia. People from UNESCO are interested. When they came to Moscow and observed, they said, "This is something we can recommend to other countries."

CONCLUSION

Environmental education is a very difficult problem. Various forms of environmental education have to be used. I felt very happy yesterday, for example, when quite a few people, under the guidance of Professor Stuardo, discussed that subject. I felt very happy that we could achieve some of the final recommendations about the ways to proceed with this subject. We do need international cooperation in this field. I think that if students from various countries can get together with a team of international experts who can teach them the environmental sciences—particularly marine environmental sciences when we are talking about the sustainable development of the Pacific—it would be one of the ways young people could get a modern education, as well as understand each other better than they do now.

DISCUSSION

*(**Praskovya Gogoleva**, Yakutsk State University.)*
What environmental sciences textbooks and manuals do you use at the Open Ecological University?

Petrosyan. Currently, there are not very many textbooks available. Each of the professors is mostly using the knowledge he or she has been accumulating for many years. The value of those people is very high. There are only a very few good books in the complex field of environmental sciences. I would prefer, of course, to have specialized books in the particular field of environmental sciences, such as environmental biology, environmental chemistry and toxicology, geoecology, economics and law and so on. For instance, I haven't seen any good books on industrial ecology, which is a kind of funny term but it is about how industries affect the environment. Maybe in the near future such texts will be available.

(***José Stuardo***, *Universidad de Concepción, Chile.)*
In my country, we had a visiting German specialist who spoke about German water quality regulations, which are very complex. Is a simplification of such regulations possible?

Petrosyan. This is very complex question because different countries use different regulations. I've been visiting several stations of this type in Germany, and water in Germany costs a lot of money because of their water quality standards and regulations. The regulations in different countries are very different, and looking through them, I realize that in some places—just to keep the price of water on the appropriate level—only look for the compounds that they consider to be the most typical. In the United States, for example, people look mostly for the trihalomethanes, but of course since they are looking only for particular compounds, they can miss something. In some cases, the water contains compounds that could never be predicted. The water may contain inorganic pollutants like heavy metals, nitrates, nitrites and other things, including radionuclides. From that point of view, the ideal is a complete analysis of every sample of drinking water you supply. But that would cost a lot of money, so the price for the water would be very high. In reality, you have to be somewhere in between. It is also true that water safety is difficult to determine because you have no idea about the toxicities of at least a third of the compounds you see. In the Moscow city drinking water, we couldn't find the toxicological data for at least 30% of the compounds. As a result, we've been trying to create a computer data bank on these organic compounds.

(***Syun-Ichi Akasofu***, *University of Alaska Fairbanks.)*
At the present time, unless scientists are specialized in the one area, they cannot survive as scientists, yet the issues that you deal with are very, very interdisciplinary. How can we reconcile these concerns?

Petrosyan. You are absolutely correct. This is why when there was a proposal to found an environmental sciences department, the scientific council of the university decided against it. If students are taught physics, chemistry, biology, geography, geology, law, and economics, all together, they will know something in each field, but will be not specialists in any of these fields. The idea of the Open Ecological University is to give a general environmental education to students who are already specialized in one of the sciences.

(***Miguel Fortes***, *University of the Philippines.)*
In the Philippines, we have proposed a very ambitious program for a master of science and Ph.D. in environmental science. We even went to the extent of incorporating not just those lecture programs that you mentioned, but we tried to incorporate art and philosophy. I agree with you that one person cannot specialize in so many things. A week from now, there will be a meeting of our faculty to discuss the same problem, but my point of view has been reinforced by your opinion.

(***Terry Gacke***, *University of Alaska Fairbanks.)*
This question is for Professor Bridges as well as Professor Petrosyan. How can you ensure that traditional cultures living in these environments are considered and that their opinion is included in the decisions the scientists make, in the gathering of data, the interpretation, and then the final education?

Bridges. It's a serious problem, and we have special programs at the University of Hawaii that bring in the Natives of the region. We're trying to build a scientific base with them. But we've found that even in the conservation area, once we have control of the lands, even as scientists and managers, the real job is how do you communicate the management practices with the Native population; you can't separate the two, and it's a much harder problem than most of the technical problems. How do you communicate what's happening? If you don't have agreement, you can't have the long-term preservation of the lands.

Petrosyan. I would like to mention that if you translate the English word "environment" into Russian, you get two very long words. This is why people in my country, instead of talking about environmental problems, speak of ecological problems. Instead of using the term environmental education, we would call it ecological education in Russian. This is why the program I have been talking about is called Open Ecological University, rather than Open Environmental University. Of course, we do realize the difference between ecology as a part of biology and complex environmental issues. The term ecology has become so popular in our country that people speak of the ecology of soul, ecology of art. People are trying to combine approaches toward cultural development with modern trends in the environmental sciences and environmental education. This doesn't work very successfully in all cases. The concern is so great that people always will be talking about environmental problems.

(**Leandro Viloria**, *University of the Philippines.)*

I would like to suggest an alternative approach: a specialization of environmental management. Perhaps if we related to requirements of governments and how to prevent environmental pollution, or mitigate environmental pollution, we can look at the experiences of countries that have instituted environmental impact assessment systems. As educators, we should ask ourselves what curriculum we should design for our students who would be preparing environmental impact assessments.

Petrosyan. Dr. Burman, who I mentioned as the principal advisor to our Minister for Environment, had a background in chemistry, then got her Ph.D. in economics, and then became interested in environmental impact assessment procedures. Now she is a great specialist in that area.

Individuals can be physicists, biologists, mathematicians, or chemists—whatever—but if they become interested in environmental sciences, they can go for master of science or a Ph.D. in ecological economics or environmental chemistry, depending on their background. If they need more, they can be trained in centers such as the one we have in our university. They might go through a one-month program, a six-month program, or a ten-month program.

It's okay to train students specifically for environmental management, but you don't need that many people graduating from that department. A geologist or chemist or economist can work on other subjects. In half a year, a year, she or he might become a good specialist in the field of environmental management. But sometimes it's not easy to find a job for those graduates, because they are not specialists in any of the particular fields.

(**Yasyhiro Sugimori**, *Tokai University.)*

In my opinion, we must focus on environmental systems as a whole—issues like the increase of carbon dioxide and the greenhouse effect and how this abnormal climate or ocean pollution may affect global-scale ocean and atmosphere interaction. We must study how larger environmental systems are influenced by studying the small-scale environmental systems to which we have access, for instance coastal region pollution, inland pollution, and air pollution in cities. Somehow, large-scale pollution systems are affected by small-scale pollution. We must consider the pollution of such environmental systems. After that, things might be systematically organized into scientific fields, for instance chemistry or biology. We must think in terms of global-scale environmental pollution systems, then input every kind of specialized category, and mix them together for more detailed analysis. What do you think about this concept?

Petrosyan. To solve such complex problems, I suggest scientific teams composed of a physicist, a chemist, a biologist, a soils scientist, a geographer, a geologist, and a mathematical modeling person. Each would provide depth of understanding within their respective fields. The result would be much higher quality than with ten people who have all graduated from an environmental sciences department but are not specialists in particular fields.

North Pacific Ecosystems: A PICES Priority

Warren S. Wooster
University of Washington
Seattle, Washington, U.S.A.

OVERVIEW

The collapse of the California sardine fishery in the late 1940s illustrates that change is inevitable in oceanic ecosystems, that it may occur regardless of human activities, and that its anthropogenic and natural causes are often difficult to distinguish. Even the health of the ecosystems is difficult to monitor since key components are not regularly harvested. To determine the impacts of human activities such as fishing and pollution requires understanding of how the ecosystems work; otherwise, rational management of harmful activities depends on myth and prejudice rather than on science and reason.

To facilitate the interactions necessary to achieve such understanding among the disciplines, universities, and agencies of the northern North Pacific, the North Pacific Marine Science Organization (PICES) was established in 1992, with Canada, China, Japan, and the United States as charter members. As an international organization, PICES has a broad interest in ecosystem questions which are being addressed by its committees and working groups. In addition to its scientific activities, PICES could become a mechanism for providing objective scientific advice to its members and to fishery and pollution management commissions in the region.

UNDERSTANDING MARINE ECOSYSTEMS

The Conference of Asian and Pan-Pacific University Presidents is properly concerned with the health of oceanic ecosystems, since these systems are sources of food, employment, economic wealth, and pleasure, among other things. There are few who would oppose such concern, but there is no broad agreement on how such health can be determined, let alone maintained or improved. Let me illustrate with the parable of the California sardines.

The collapse of the California sardine fishery in the late 1940s appeared to be a prime example of the destruction of an ecosystem through overfishing (Figure 1). Like all other collapses of marine stocks, this was apparently the consequence of improper human activity; but skeptics have existed since the event, and their ranks have multiplied as evidence accumulates. Variation is the norm among animal populations in the sea. Are only the declines to be attributed to man? Was it coincidence that the Far Eastern stock of sardines declined—and recovered—at about the same time (Figure 2)? The most convincing evidence comes from studies of fish scales in offshore sediments (Figure 3) which reveal the history of sardine abundance off the California coast. The 1940s crash is obvious, but so are others near the turn of the century and earlier, when the only mortality was natural. A recent extension of these data (Figure 4) shows that the California sardine and anchovy stocks have been exploding and collapsing for nearly two thousand years.

The moral of this story is that change is inevitable in oceanic ecosystems, that it may occur regardless of human activities, and that its anthropogenic and natural causes are often difficult to distinguish. Furthermore, it is not easy to detect and measure such change, because only the fish and shellfish stocks of commercial interest are regularly monitored. Suppose, for example, that the health of the ecosystem really depends on krill or sand lance or some other species that only the non-human predators keep track of? Fortunately, the record of climatic forcing, at least, is somewhat more complete.

Of course, fishing is only one category of human activities that affects marine ecosystems. Another includes the various human introductions into the sea—pollutants, pathogens, nutrients, debris, exotic species. These presumably all have

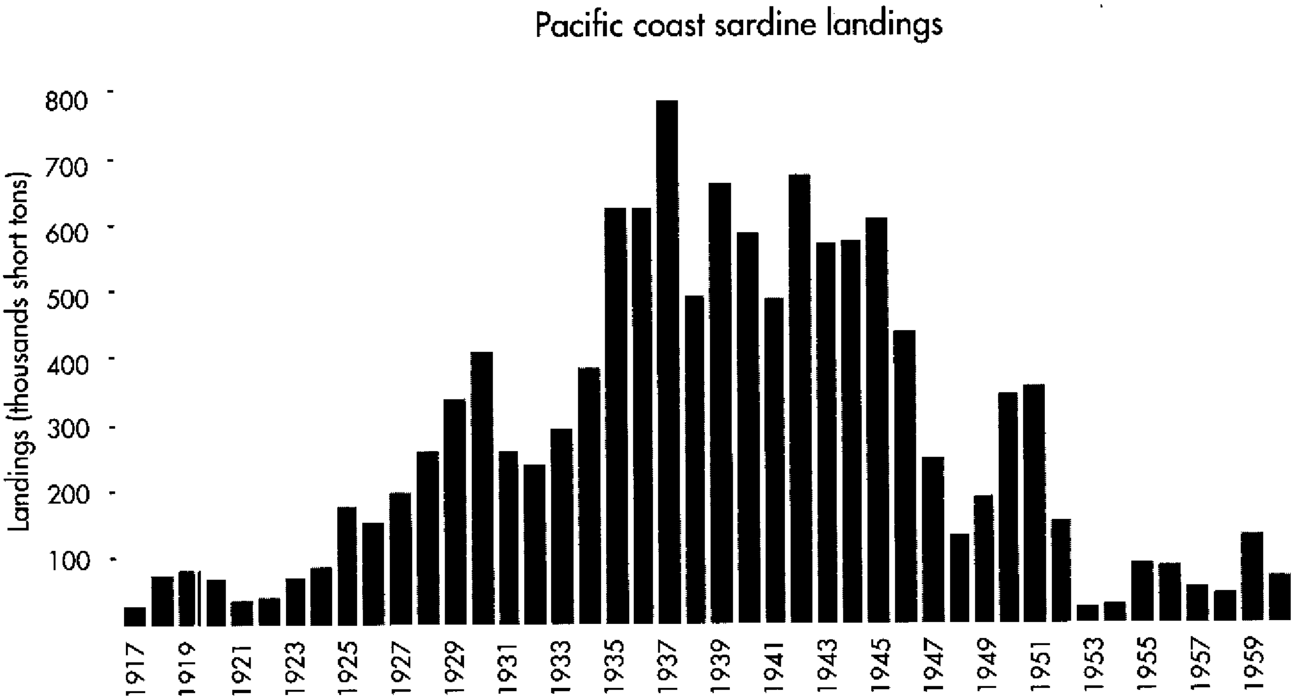


Figure 1. Pacific coast sardine landings, 1917–1960. Based on Murphy, 1977, Table 38.

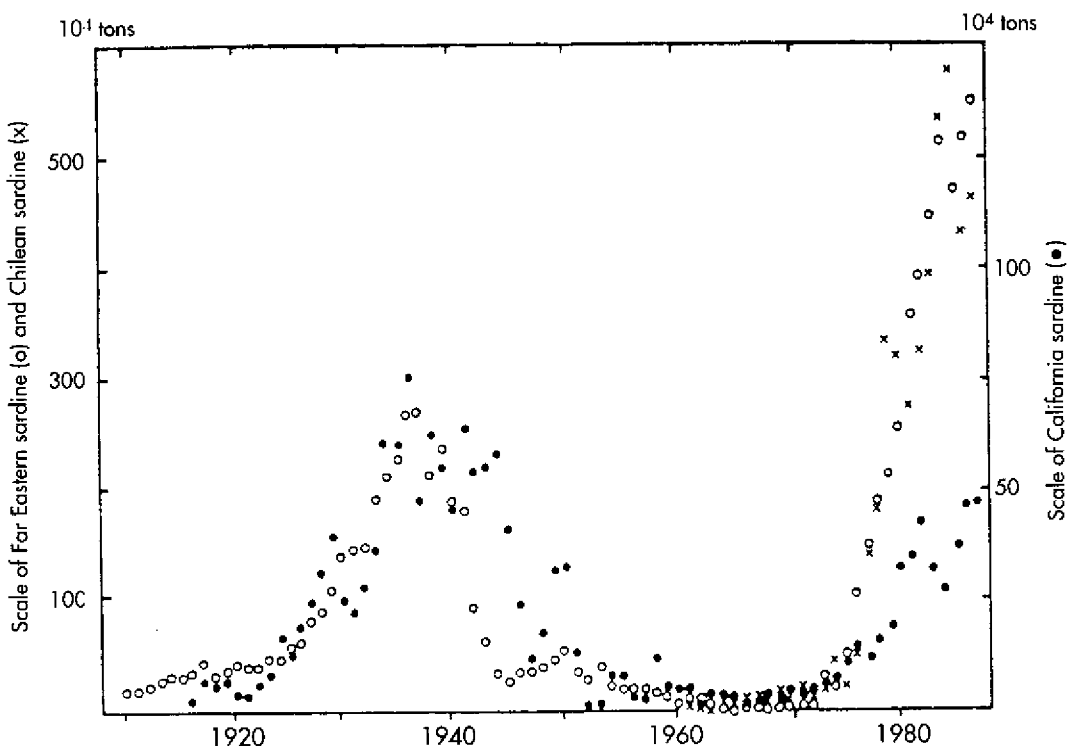


Figure 2. Trend in catch of Far Eastern, Californian, and Chilean sardines, 1910–1987. From Kawasaki, 1991, Figure 2.

impacts, but the same problems arise—how to measure the human contribution, how to keep track of ecosystem change, and how to distinguish between anthropogenic and natural forcing of change. Another problem, perhaps the most serious and common to both extractive and injective uses, is the lack of understanding of how these ecosystems work. Without this, rational management of harmful human activities is difficult to justify and sustain, and regulation becomes a creature of myth and prejudice rather than of science and reason.

To achieve ecosystem understanding and to monitor ecosystem change effectively in the North Pacific requires the pooling of talents in disciplines and laboratories of universities and government agencies in the countries of the region. The problem is as much physics as it is biology, and the long view of university research is as essential for its resolution as is the shorter-term more focused emphasis of government agencies. Some fifteen years ago, we initiated efforts to create a new international organization to promote marine science and to facilitate the necessary interactions in the region. This organization, the North Pacific Marine Science Organization (PICES) came into existence in March 1992 with Canada, China, Japan, and the United States as initial members. The Soviet Union was a party to the negotiations, and Russia is expected to join in the near future as, we hope, will Korea.

The organization will function in the North Pacific, especially north of 30°N. As delineated by the third article of the PICES Convention, the purpose of the organization is twofold:

> (a) to promote and coordinate marine scientific research in order to advance scientific knowledge of the area concerned and of its living resources, including but not necessarily limited to research with respect to the ocean environment and its interactions with land and atmosphere, its role in and response to global weather and climate change, its flora, fauna and ecosystems, its uses and resources, and impacts upon it from human activites; and (b) to promote the collection and exchange of information and data related to marine research in the area concerned.

Most relevant to our discussion is the central question identified by a PICES workshop:

> What is the nature of the subarctic Pacific ecosystem (or ecosystems), and how is it affected over periods of months to centuries by changes in the physical environment, by interactions among components of the ecosystem, and by human activities?

Indicative of the broad approach of PICES, it has four standing scientific committees—biological

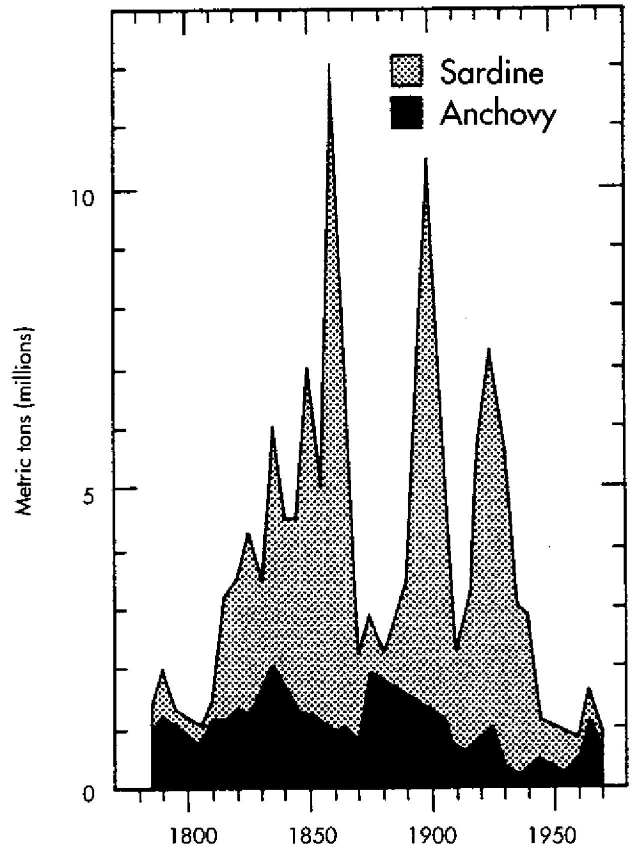


Figure 3. Spawning biomass of Pacific sardine and northern anchovy, 1790–1970. From Smith and Moser, 1988, Figure 1.

oceanography, fishery science, marine environmental quality, and physical oceanography and climate. To develop its scientific program, the organization has established six working groups—on the Okhotsk Sea and Oyashio region, on the Bering Sea, and on the subarctic gyre, on the dynamics of small pelagics in coastal ecosystems, on methodology for marine pollution, and on data collection and quality control. A charge to the subarctic gyre working group illustrates the ecosystem emphasis:

> Review existing information on the carrying capacity for salmon and other nektonic species in the subarctic, and what is known about variations in the carrying capacity of this region in response to climate change.

All of these groups are coordinated by the Science Board of PICES. The Secretariat is established in Sidney, B.C.; the Second Annual Meeting took place in Seattle the week of October 25, 1993.

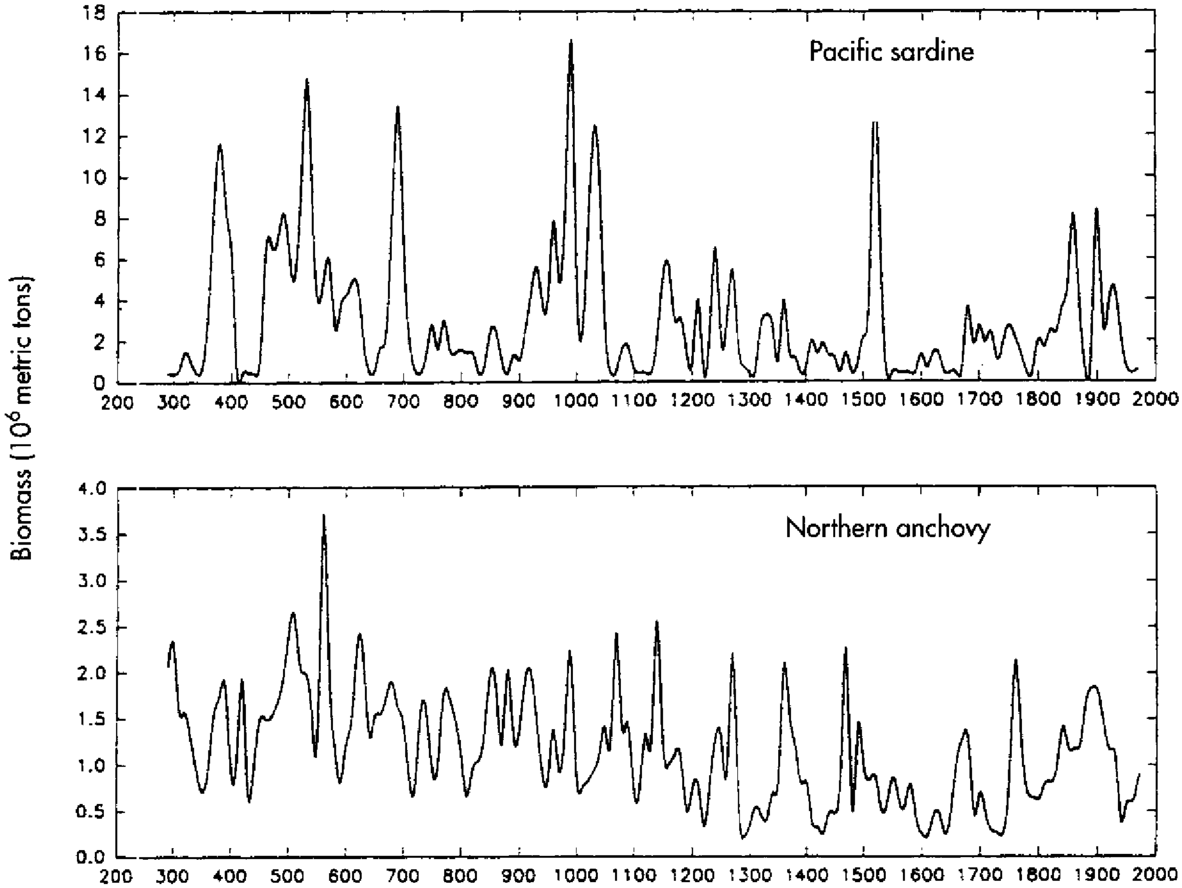


Figure 4. 1,700-year hindcast series of Pacific sardine and northern anchovy biomasses off California and Baja California. From Baumgartner et al., 1992, Figure 7.

CONCLUSION

PICES—the Pacific ICES—was patterned after the International Council for the Exploration of the Sea (ICES), which has operated in the North Atlantic since 1902. One of the functions of ICES (which, like PICES, has no management authority) has been to furnish objective scientific advice to its members as well as to fishery and pollution management commissions in its region. A similar role was envisioned for PICES. As Secretary of State James Baker wrote to President Bush in recommending ratification of the PICES Convention:

> Separation of scientific and management functions in this fashion should help ensure that the scientists are not swayed by political or economic factors during their scientific deliberations and that the scientific information and advice they provide will be completely unbiased. This will assist the managers, whether in a member State or an international regulatory body, to make the best possible decisions based upon the scientific facts.

The North Pacific countries have yet to pursue this use of the new organization.

I am hopeful that as the activities of PICES develop, they will make a useful contribution to the purposes of this conference and that we can find an effective way to work together to achieve our common goals.

REFERENCES

Baumgartner, T.R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. CalCOFI Rep. 33:24–40.

Kawasaki, T. 1991. Long-term variability in the pelagic fish populations. In: T. Kawasaki, S. Tanaka, Y. Toba, and A. Taniguchi (Eds.), Long-term variability of pelagic fish Populations and their environment, pp. 47–60. Pergamon, Oxford Elsevier Science Ltd., New York.

Murphy, G.I. 1977. Clupeoids. In: J.A. Gulland (Ed.), Fish population dynamics, pp. 283–308. John Wiley, New York.

Smith, P.E. and H.G. Moser. 1988. CalCOFI time series: An overview of fishes. CalCOFI Rep. 29: 66–78.

Working Group Reports

This summary report was prepared by the symposium secretariat from notes provided by the various working groups.

MARINE ENVIRONMENTAL EDUCATION

The group endorsed the concept of a floating university of marine science. It was agreed that an international approach to ship-based marine ecological education and research in the Pacific basin would be of mutual benefit.

The group endorsed the strengthening of existing marine educational programs throughout the region and noted that the program proposal "Strengthening the Development and Applications of Coastal Oceanography in Southern South America: Facing Global Changes and Environmental Protection," presented by Prof. J. Stuardo, is an important model in this area. The group also noted that needs for marine environmental education extend beyond university training of specialists and that university museums of science and natural history play an important role in this context.

The group endorsed the concept of an international cooperative effort to assess plastic pollution in the Pacific region through periodic, coordinated beach surveys. Involvement of pre-college students in such a program may increase knowledge of marine science and foster international awareness.

The group endorsed the proposal of the Russian Academy of Science and the Far Eastern State University to create an International Chair of Marine Ecology with the cooperation of UNESCO.

The group endorsed cooperative projects of student exchange among universities of the region and recommended development of a plan for mutual recognition of educational stages and standards to facilitate international transfer of students among academic institutions of the Pacific.

The group endorsed a call for the integration of social, cultural, and scientific information in resource management and for freedom from political interference in expression of opinions on these matters.

The group noted with interest the announcement of a seminar devoted to the environmental problems of Far Eastern seas to be held aboard ship for two weeks in September 1994 by the Far Eastern State University, Vladivostok, Russia.

SUSTAINING THE PACIFIC

The group endorsed a proposal to plan for joint research concerning the accumulation of radiological and synthetic organic toxins in marine food webs.

One primary focus of this joint research will be toxins that are associated with chronic disease in humans.

COASTAL AND HIGH SEAS MONITORING

The group endorsed the creation of scientific teams containing representatives of interested institutions. These teams would be devoted to the identification of regional issues and areas of concern, and would suggest methods of assessing and addressing these issues.

The group recommended exploring how the activities of the Conference of Asian and Pan-Pacific University Presidents relate to those of other scholarly bodies concerned with the Pacific region including PICES, the Space Agency Forum International Space Year, The Congress of Pacific Science Associations, and others that may be identified.

The group endorsed the continuation of the Conference's work in the field of satellite monitoring of drifting buoys.

The group endorsed the formation of a team devoted to information processing and data exchange, both remote sensed and in situ, among interested institutions of the Pacific region.

Ecological Problems and Monitoring of the Far Eastern Seas

Peter F. Brovko
Far Eastern State University
Vladivostock, Russia

The ecological problems of the Far Eastern Seas coastal zone are a result of both anthropogenic and natural processes. Pollution of these coastal waters takes place in the ports and nearby waters—regions of mining development, oil-extracting industries, and integrated pulp-and-paper mills (with the resulting waste discharge). Exploitation of sand for construction in coastal zones results in sediment shortage and increasing coastal erosion.

Natural hazards (i.e. volcano eruptions, earthquakes, and tsunami) make the ecological situation worse. During typhoons, the rise of water levels causes flooding of farming lands, roads, and railways. The increasing suspended load drainage basin and the changing hydrochemical regime result in degradation of biogenesis in the coastal zone. We should take into consideration the rising of the sea level.

The Coastal Research Center of Far Eastern University carries out coastal monitoring of twenty main locations on the shore of the Sea of Japan, the Sea of Okhotsk, and the Bering Sea. The project on LOICZ (Land-Ocean Interaction in the Coastal Zone) includes coastal monitoring as a part of its investigations. Cooperation in coastal monitoring will be planned in the Northern Pacific with Tokai University, Western Washington University, the University of Alaska, etc.

The Coastal Ecosystems of the ASEAN Region: A Vanishing Frontier?

Miguel D. Fortes
University of the Philippines
Quezon City, Philippines

The seas of the ASEAN region comprise 8.9 million km^2 or 2.5% of the world's oceans. They form a part of the center of generic richness and maximum variety of species that compose the coastal ecosystems of the tropical world—coral reefs, seagrass beds, and mangroves. Unfortunately, regional efforts to improve the quality of life of its rapidly increasing population include massive industrialization and infrastructure development which is predicated upon environmental exploitation, not protection. With varying degrees, soil erosion has enhanced sedimentation in the coastal and marine ecosystems, making coral reefs particularly vulnerable. Pollution from land-based sources has impacted enclosed or semi-enclosed areas where mangroves and seagrasses occur, while reclamation and other development activities are causing the loss and destruction of the coastal habitats. This is exacerbated by destructive fishing methods (for example, dynamite and poison fishing) and overexploitation of many resource and endangered species from the ecosystems, such as sea cows, sea turtles, and giant clams from seagrass beds and coral reefs.

Regional efforts to reverse these trends include watershed and coastal zone management, pollution control, environmental impact studies, protected areas, adherence to the provisions of wetlands and world heritage conventions, and legislation. Whether these efforts will succeed depends largely upon a reversal of the prevailing regional view that "nature does not pay, but coral, fish, and logs do."

Environmental Influences on Salmon Migration in the Northeast Pacific

Paul LeBlond and Keith A. Thomson
University of British Columbia
Vancouver, British Columbia, Canada

Computer simulations have been performed to investigate the influence of ocean currents on the migration of adult sockeye salmon toward the coast of British Columbia. Surface currents are obtained from a superposition of daily wind-driven flows and an average geostrophic circulation. Results show important interannual variations in latitude of landfall of up to 550 km and variations of time or arrival of up to two weeks at the coast. These results will be interpreted in terms of features of the surface circulation of the Alaska Gyre and in the light of other effects responsible for the variance in observed characteristics of the migration process.

Spring Sea Ice Conditions from SAR Images Near the Alaska Coast of the Chukchi

Fucheng Li, John Kelley, and Eriko Uematsu
University of Alaska Fairbanks
Fairbanks, Alaska, U.S.A.

Sea ice in the Chukchi and Beaufort seas has been a major subject of interest, with emphasis on aspects of environmental forecast, offshore engineering, and navigation. Less effort has been put on its relation to marine life inhabitants, including whales. Indeed, sea ice is a major determinant of distributions in time and space of living marine organisms in these areas. Native people of the Arctic associate the distribution and movements of marine species with sea ice characteristics or conditions. They deal with the hazards of sea ice while hunting for ice-inhabiting species such as seals, walruses, seabirds, and particularly bowhead whales.

The bowhead whale inhabits the Arctic/subarctic regions, principally in or near the sea ice zone of the continental shelf and oceanic water of less than 1000 m depth. One of their principal migration routes in springtime is from the Bering Sea northward to Point Barrow along a flaw lead zone of sea ice at the eastern Chukchi Sea, and via offshore leads to Banks Island, Beaufort Sea. Observations show a strong effect of sea ice lead and sea ice thickness on the bowhead whales' migration.

China's Environmental Problems and Fudan University's Research Programs in the Environmental Sciences

Xu Ming-zhi
Fudan University
Shanghai, China

The Issue of Overpopulation

During the past decade, like many other developing countries, China has felt the great pressure of population growth, even though it has achieved great success in its economic development. It is well known today that our planet holds more than five billion people, of which about 1.1 billion are Chinese. It is expected that the world population might be doubled in the next century, with 90% of the growth occurring in developing countries where the population outgrows the national resources in providing the necessary housing, fuel, and food. Forests have been excessively cut for fuel, meadows overgrazed by livestock, and farmlands overtilled by desperate farmers. As a result, the whole ecological system has been seriously disturbed.

To tightly control population growth, the Chinese government has carried out a "one family, one child" policy which aims at limiting the population to 1.2 billion by the year 2000. The implementation of this policy has been quite successful in the urban areas, but it has not been very effective in the rural areas where manual labor is in great demand. The total population might reach 1.25 billion by the end of this century. Therefore it should be the duty of educational institutions of all levels to educate their students and general public about the importance and significance of population control.

The Hazard Caused by Pollution and Overexploitation of Natural Resources

As a consequence of rapid economic development and fast population growth during the past decades, China is now confronted with many serious environmental problems:

1. Pollution by coal burning. Coal consumption was estimated at about one billion tons in 1989. This is a major source of air pollution in many big cities of China and it contributes significantly to global warming.
2. Water pollution from factory waste disposal and other sewage.
3. The conservation of forest, soil, and water has been neglected during recent years of economic development. Although measures have been taken in building up forests in the northwestern area, the percentage of forest coverage is still diminishing. The degradation of farmland into desert is becoming a serious problem.
4. Residents in urban areas become victims of noise pollution.

In order to protect the environment, various laws and environmental protection regulations have been issued, and administrative agencies for managing environmental issues and monitoring pollution have been established; however, problems still remain for the effective implementation of all the necessary regulations.

The Dilemma Between Ecological Protection and Resource Availability

It is very easy to pollute the environment, whereas it is extremely expensive to get rid of pollution and bring laws for environmental protection into full implementation.

The greatest challenge for the government is to exert effective control on the protection of environment while maintaining a sustainable economic growth so the living conditions of future generations improve.

Sometimes drastic measures should be taken, such as moving some of the factories to the suburbs or shutting down those that cause serious pollution, even at the expense of affecting the production for a time. Management and monitoring systems should be improved.

The Role of the University in Environmental Protection

The basic solution of population and environmental problems lies in upgrading the education level of the people. It is the consensus of both government leaders and educators that institutions of higher learning must play an important role in saving our environment from further pollution. In order to meet this urgent need, the Institute of Environmental Science was established in 1985 at Fudan University, with the purpose of bringing faculty members and students from various departments such as biology, chemistry, physics, and mathematical mechanics, as well as those from social science departments such as economics, law, and business administration to carry out research work and develop curricula in certain aspects of environmental science relevant to the expertise of the university. All participating faculty members and students remain in their respective departments. The Institute coordinates the multidisciplinary research programs that are relevant to environmental science and offers courses forming an interdisciplinary curriculum.

The Institute's major goal is to study the strategic policies on population control, the correlation of population control and environment, and to raise the environmental consciousness of faculty members and students who take part in the Institute-sponsered research programs. It is hoped that the results of our research work will draw the attention of government agencies at all levels.

The Institute also cherishes the idea of international cooperation on issues concerning our global environment.

There are six divisions in the Institute:

- *Environmental Ecology*. This division is interested in the effects of environmental pollution on the aquatic and terrestrial ecosystem and problems concerning ecobalance which might be helpful in promoting the growth of agricultural products.
- *Environmental Economics*. The major interest is the relationship between economic growth and environmental pollution as well as to carry out research work concerning the assessment of environmental quality and managemental protection for the urban areas.
- *Environmental Law*. This division is responsible for carrying out research work on laws, regulations, and policies concerning environmental protection and environmental management.
- *Environmental Mechanics*. This division deals with the transport and distribution of pollutants in the process of industrial waste treatments based on both experimental and theoretical studies.
- *Environmental Monitoring*. The major role of this division is to conduct research in the qualitative and quantitative analysis of environmental pollutants based on basic principles in physics and chemistry.
- *Environmental Chemistry*. This division consists of four research groups: water chemistry, atmospheric chemistry, environmental radiochemistry, and environmental biochemistry.

As for the relationship between population control and environment, the Institute works in close cooperation with the Institute of Demography of Fudan University.

At the moment the Institute is staffed by 150 full-time and part-time faculty members; among them are about 40 professors and associate professors. About 20 courses on environmental sciences are given to both undergraduate students and graduate students of the university.

Pollution of the Coastal Zone in the Japan Inland Sea

Shiro Okabe
Tokai University
Shizuoka, Japan

Sedimentation rates of suspended substances in Tokyo Bay and Osaka Bay were 0.15–0.23 cm/yr and 0.12–0.61 cm/yr, respectively. These were higher than the values in other bays of Japan.

Sediment samples were collected by the piston corer in Tokyo Bay. Vertical distribution of concentrations of copper, lead, nickel, zinc, and chromium was studied with the date of sedimentation by the ^{210}Pb method in bottom sediments. The analyzed metal contents all had been increasing from 1880 to 1970 when most marked changes were found; but since 1970, metal content has gradually decreased. This is attributable to the fact that the waste discharged from inland areas into seawater was reduced in compliance with the Marine Environmental Protection Law concerning inland seawater.

The oxygen deficiency of water in the bottom layer of eutrophic inland sea is exerting adverse effects on marine organisms. One of the causes is the blooming, death, and decomposition of phytoplankton. In recent years, the eutrophication of the inland sea has been inhibited by the water quality regulation of waste waters.

However, oxygen deficiency in the bottom layer continues and the productivity of marine organisms is on the decline.

The relationship between the distribution of red tide phytoplankton in coastal water and the accumulation of organic substances in the sea bottom was also considered. If dissolved oxygen in seawater is entirely consumed by the decomposition of marine organisms, the resulting anoxic condition creates a poisonous hydrogen sulfide.

The Role of Data Acquisition from Satellite-tracked Drifting Buoys

Toshibumi Sakata
Tokai University
Tokyo, Japan

Seventy percent of the surface of the earth, which is also called the "aquaplanet," is covered by water, giving life to its animals and plants. This is a contrast to the other planets. Animals and plants receive energy radiated by the sun and each maintains its life in its own way. The sea absorbs and stores solar energy, helping to maintain a good terrestrial environment. The world's weather conditions depend on the complex relationship between the continents and seas. In particular, the seas exert an important effect upon climate. Oceans such as the Pacific—which occupies almost 50% of the earth's area—seriously affect not only weather conditions but every living thing. Since the dawn of history, humans have enjoyed the benefits of the sea, but we have failed profoundly in our duty toward the environment. From the latter part of the eighteenth century to the present, humans have unceasingly contaminated the sea, taking advantage of its mighty ability to purify and produce.

Difficulties have already shown themselves in various phenomena. Accumulation of waste plastic materials, for example, is creating what will eventually become a heap along the Alaska coast, while years of irresponsible fishing has destroyed a considerable portion of the ocean's food resources. Further, the matter is growing worse because those accidents, including large-scale efflux of petroleum and the dumping of chemicals in the sea, are straining local as well as global resources.

The biological condition of the Pacific Ocean must be maintained unmarred to assure our own social welfare, economic prosperity, and public peace, not only in this area but throughout the world. Challenges of enormous importance and daunting difficulty will decide the destiny of future generations.

In August 1991, the Third International Symposium of the Conference of Asian and Pan-Pacific University Presidents was held in Vladivostok. Most of the discussion centered on environmental questions at the global level, including sea contamination in the North Pacific area. Dr. Tatsuro Matsumae, President of Tokai University, said, "We are destined to bear responsibility for protecting the sea, because our life originated in and was fostered by our mother sea." He then proposed "environmental surveys in the North Pacific area to be operated via artificial satellites to cope with contamination of the global environment, seeking the counsel of many universities, without regard to international boundaries." The result was a decision to carry out a study to determine the true nature of water currents in this area. In January 1992, the first meeting was held at Tokai University Pacific Center in Hawaii. Presidents and students of Alaska, Hawaii, and Canadian British Columbia universities gathered to debate implementation of the decision. According to the plan, 100 ARGOS buoys were to be dropped off the coast of Okinawa on the western side of the Pacific. They were expected to float across the Pacific on currents from the west, down to the eddy northeast of Hawaii. Three kinds of buoys were prepared with drogues attached underneath to sense the varying conditions at levels corresponding to surface, sub-surface (0–10 m), and central (10–20 m) currents.

On October 7, 1992, a series of buoys was dropped off Okinawa, Ensyunada, Izu, and Sanriku to ride the currents. In January 1993, some buoys reached almost 165°E. They were expected to reach the eddy during the summer of 1993. It was estimated that 30% of the buoys would arrive there.

Biochemical Monitoring of Bowhead Whales Caught off Barrow, Alaska: Serum Protein and PCB Levels

Cynthia M. Simons, Beverly Johnson, Lawrence K. Duffy,
Eric Follman, and John Kelley
University of Alaska Fairbanks
Fairbanks, Alaska, U.S.A.

Observing important biochemical markers such as serum proteins and immune function can provide long-term documentation of acute and chronic effects of exposure to pollutants on the health of wild populations of mammals. Gel electrophoresis of total serum proteins was used to resolve the protein pattern into multiple zones. These zones were quantitated by densitometry and total protein in the sample was measured by the Bradford method. Total serum protein of the bowhead whales ranged from 9.0g/100 ml to 11.7g/100 ml with a mean of 10.5g/100 ml ±SD of 0.84. For 18 bowhead whales, the relative concentrations of serum proteins present in the different electrophoresis zones was: (SD) albumin, 31.1% (5.9); α_1, 11.2% (2.5); α_2, 17.0% (3.6); β_1, 10% (3.8); β_2, 9.7% (3.0); γ, 21.6% (3.6). PCB levels in red blood cells were below detectable levels of 0.5 ppm.

Underground Nuclear Explosions and Global Nuclear Fallout: Impact on Yakutia

V.E. Stepanov, S.I. Degtyaryev, A.A. Alekseev, Z.E. Petrov (Yakutsk State University, Russia); G.I. Borisov (Kurchatovsky Institute, Moscow, Russia); and A.V. Stepanov (Radium Institute, Saint Petersburg, Russia)

The main sources of radioactive pollution in Yakutia are the prospecting of uranium deposits, radioactive pollution from the underground nuclear explosions, and global fallout. In collaboration with Kurchatovsky Institute (Moscow) and the Radium Institute (Saint Petersburg) the laboratory of radioactive ecology at Yakutsk State University does research work in radioactive ecology. Two scientific expeditions and a number of local investigations were carried out near the underground nuclear explosions.

Field semiconductor spectrometry determined that the level of accumulated ^{137}Cs on the surface soil downstream of the Lena River makes up 2 KBK/m^2, half of which was caused by the Chernobyl disaster. Downstream of the Vilyuj River, the background makes up 4 KBK/m^2. The most nuclear contamination was discovered in the samples from the regions that suffered from the underground nuclear explosions near the villages Udachny and Taas-Yuryakh. The level of pollution makes up 40 KBK/m^2 on ^{137}Cs and 3.5 KBK/m^2, five times more than the corresponding data near the Chernobyl accident.

There are two places of nuclear underground explosions with intensive radioactive contamination and several places with low radioactivity background. It is imperative to organize an international laboratory on radioactive ecology with the aim of carrying out investigations on the influence of local radionuclides on the environment and the way they transfer to the Pacific region.

Natural and Anthropic Impacts and Disturbances on the Central and Southern Coasts of Chile

José Stuardo
Universidad de Concepción
Concepción, Chile

The west coast of southern South America, one of the most productive areas of the southeastern Pacific, presents a set of environmental characteristics, combining climatic conditions determined by latitude, a distinct pattern of oceanic circulation and orogenesis. In fact, diastrophism in the area continues to occur with major changes due to tectonic movements in the earth's crust configuring the coast, and comparatively minor but recurrent local fault adjustments (earthquakes).

In turn, the increase of coastal populations and related socioeconomic development is determining changes, mostly unfavorable to nature, many of which are detected only when the effects threaten human welfare or reach the public eye. Unfortunately, regulations to prevent and counteract them are not embodied in only one set of legislation.

A general discussion of the main positive and negative impacts and disturbances is presented, including:

1. *Natural impacts*, such as local uplifiting or sinking of the coast and ensuing tsunamis; changes in oceanic currents impinging on the coast of Chile; seasonal upwelling of equatorial subsurface waters; river input of sediments, nutrients, and pollutants; and red tides.
2. *Anthropic impacts*, such as land and wetlands utilization; effluents and dumping due to urban development of coastal population and industrial development involving hydroelectric power, pulp and paper mill, timber and forestry (sawdust, chips, wood); oil refining; fish processing and fishing; and aquaculture.

Analysis of Drifting Buoy Experiments in the North Pacific Ocean

**Yasuhiro Sugimori, Akira Nakamura, Masao Fukasawa,
Toshifumi Sakata, Haruhisa Shimoda, and Kohei Cho
Tokai University
Tokyo, Japan**

Tokai University deployed twelve ARGOS floats in the Kuroshio region in the south and the east of Honshu, the main island of Japan, from September to November, 1992. All of them drifted along the Kuroshio for one or two weeks after their deployment, but some of them diverged from a strong current path when they entered the Kuroshio Extension.

In this paper, two groups of drifters, which never diverged even on the Extension at least to the west of the dateline, are used to show characteristics of the divergence field of the current along the western portion of the Kuroshio Extension.

One group was composed of three drifters and another was composed of four drifters. The divergence of the current field was estimated by time and/or space derivatives of areas of the triangle and the square.

Results showed that the magnitude of the divergence estimated by the first group was uniform over our oceanic region, and a mean time derivative of the area (i.e. eddy diffusivity) was 2.1×10^9 cm^2/sec. But the second group shows a large space and/or time variation in the magnitude of divergence. To the west of 170°E, the mean time derivative of the area was 1.4×10^9 cm^2/sec; nevertheless it turns out to be negative as -1.8×10^9 cm^2/sec in late spring 1993, or in the east of 170°E.

Why these different divergences were estimated is still not clear, but it is possible the Ekman drift may have changed in the east of 170°E in spring 1993. It is desirable to check the recent wind field around the latitude of the Kuroshio Extension. We are making efforts to get sea surface wind data in late winter and spring.

National Parks of Yakutia?

O.N. Tolstikhin
Yakutsk State University
Yakutsk, Russia

The Republic of Sakha (Yakutia) currently lacks national nature parks, though there are several areas designated as animal refuges or animal species breeding areas. At the same time, areas of environmental degradation are increasing with dangerous rapidity.

Establishment of national nature parks is considered an urgent and necessary measure to ensure environmental conservation and preservation of the traditional utilization of the environment by the aboriginal populations.

National parks, with controlled access, will also permit development of tourism, for sport, recreation, and education.

Yakutia has designated two proposed national park areas: Lena Pillars, in the watershed area between Lena and Buotoma rivers, and the Moma Valley, within the Indigirka River basin depression in the southeast of Yakutia.

National park establishment faces severe problems due to:

1. Lack of Russian and Yakutian laws regulating the establishment and maintenance of national parks.
2. Apprehension on the part of the aboriginal peoples that park administrations will be agents of oppression.
3. Inflation and consequent lack of funds for planning, establishment, and—later on—park personnel.
4. Open opposition on the part of various bureaucratic agencies which exploit natural resources, primarily industries engaged in mineral and timber exploitation and in fur procurement.

Unless these problems are solved, the establishment of national parks in Yakutia, no matter how urgently needed, remains highly problematic.

Sustainable Development for the Pacific Region: The Contribution of UNU Research Programs

Juha I. Uitto
The United Nations University
Tokyo, Japan

One of the focal areas of the United Nations University's research program is environment and sustainable development. An independent academic body under the United Nations, the university (UNU) operates through an international network of scholars. Headquartered in Tokyo, much of UNU's research is focused on the Pacific area.

UNU's program features sustainable marine development at two levels. First, UNU promotes studies into international ocean governance. Sustainable use of marine areas and prevention of pollution requires sufficient legislation as well as institutional structures for implementation and monitoring of international treaties and agreements. The Pacem in Maribus conference on Ocean Governance: National, Regional, Global: Institutional Mechanisms for Sustainable Development in the Oceans addressed these issues. Other efforts in this area have focused on regional approaches to management of the East Asian seas.

Second, UNU promotes studies into coastal pollution and its ecological, societal, and health effects. With UNU's assistance, the International Mussel Watch Program monitoring coastal pollution is being extended to the Asia/Pacific region. Collaborative studies on the Minamata case of methyl mercury poisoning in southern Japan, and related cases elsewhere, aid our understanding of the links between marine pollution and human health.

The Pacific Rim demonstrates the need for regional and international cooperation towards sustainable development. UNU research programs promote international collaboration to this end.

A Floating International University of Marine Science in the Tropics

Leandro A. Viloria
University of the Philippines
Quezon City, Philippines

The tropical waters of the Philippine archipelago abound with the widest variety of marine life and aquatic resources. These treasures for all mankind are now endangered by misuse.

A floating international university is proposed, linked to two local educational/research networks: first, three Philippine universities with institutes or centers on marine science, fisheries, and aquatic resources; and second, two international research institutions based in the Philippines—the ICLARM and SEAFDEC.

Aside from extending basic knowledge of tropical marine science and aquatic resources, the presence of a community of scholars and scientists in Philippine seas, under the auspices of Asian and Pan-Pacific university presidents, would have a salutary effect on the efforts of local officials to protect and conserve such endangered resources.

The Department of Marine Sciences at Chulalongkorn University

Supachai Yavaprabhas
Chulalongkorn University
Bangkok, Thailand

Founded in 1917 by H.M. King Vajiravudh (Rama VI), Chulalongkorn University is the oldest university in Thailand. It was named in honor of King Rama V for it was in his reign that modern education in Thailand began to develop. In succeeding years, Chulalongkorn University, or Chula as it is more commonly known, has grown to be a full-sized university offering over 270 study programs and producing over 100,000 graduates in various fields of specialization, one of which is marine science offered at the Faculty of Science.

Chulalongkorn University established the Department of Marine Science in the Faculty of Science in 1968, offering the B.S. degree for studies in marine biology and fisheries or in chemical and physical oceanography. Five years later, a M.S. program was established. Up to now, there have been 204 B.S. and 104 M.S. graduates. A Ph.D. program is in preparation, in which cooperative programs with foreign universities are planned.

International cooperation in marine science can be conducted under the coordination of either the Office of International Affairs, Chulalongkorn University, or the Ministry of Science, Technology, and Environment. The Ministry's National Research Council serves as a contact point for the Intergovernmental Oceanographic Commission (IOC) of UNESCO, whose regional body for the Western Pacific will soon be established in Bangkok. In addition, the Office of the Environmental Policy and Planning serves as a contact point for the UNEP and ASEAN Marine Science Program. At present, CU is engaged in more than ten international cooperative projects in marine science.

As part of its policy of internationalization—one of its priorities—Chula welcomes the possibility of broadening the scope of its cooperation with foreign institutions, thereby enhancing its academic expertise and intellectual capabilities in accordance with international standards of quality.

This can be achieved under agreements through various forms of cooperation such as academic exchanges and joint research projects. Hopefully, these cooperative efforts will not only be mutually beneficial, but will also contribute to the worldwide body of knowledge.

Participants

Dr. Syun-Ichi Akasofu, Director
Geophysical Institute
University of Alaska Fairbanks
Fairbanks, AK 99775-7320 USA
Phone: 907-474-7282
Fax: 907-474-5882
Internet: ffsia@aurora.alaska.edu
Omnet: S.AKASOFU!

Dr. Vera Alexander, Dean
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-7531
Fax: 907-474-7204
Internet: vera@ims.alaska.edu
Telex: 7402055 SFOS UC
Omnet: V.ALEXANDER

Dr. Douglas K. Barry, Acting Director
Alaska Center for International Business
University of Alaska Anchorage
3211 Providence Drive
Anchorage, AK 99508-8246 USA
Phone: 907-786-4300
Fax: 907-786-4319
Internet: afdkb@acad2.alaska.edu

Dr. Richard Benner, Assistant Professor
Geophysical Institute
University of Alaska Fairbanks
Fairbanks, AK 99775-7320 USA
Phone: 907-474-6576
Fax: 907-474-7290

Dr. Kent Bridges, Associate Professor
Botany Department
University of Hawaii at Manoa
3190 Maile Way
Honolulu, HI 96822-2279 USA
Phone: 808-956-6429
Fax: 808-956-3923
Internet: kim@uhunix.uhcc.hawaii.edu

Prof. Peter Brovko, Head
Geography of Asia Pacific Countries Department
Far Eastern State University
ul. Sukhanova 8
690600 Vladivostock, Russia
Fax: 7-4232-257200
Telex: 213218 FESU SU

Dr. John A. Brownell, President Emeritus
California State University,
Dominguez Hills
P.O. Box 1334
Pollock Pines, CA 95726 USA
Phone: 916-644-2388
Fax: 916-644-0733
Representing:
North American Council, International
Association of University Presidents and the
President of California State University,
Sacramento
6000 J Street
Sacramento, CA 95819-2694 USA
Phone: 916-278-7737
Fax: 916-278-6959

Dr. Keith Criddle, Assistant Professor
School of Management
University of Alaska Fairbanks
Fairbanks, AK 99775-6080 USA
Phone: 907-474-5995
Fax: 907-474-5219
Internet: ffkrc@aurora.alaska.edu

Dr. Lawrence Duffy, Professor
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775-7000 USA
Phone: 907-474-7525
Fax: 907-474-6967

Prof. Georgy Elyakov, Vice President
Far Eastern Branch
Russian Academy of Sciences
ul. Svetlanskaya 50
690600 Vladivostock, Russia
Phone: 7-4232-222528
Fax: 7-4232-228750
Internet: elyakov@piboc.marine.su
Telex: 213212 FEBAS SU

Mr. Kevin Engle (graduate student)
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-7747
Fax: 907-474-7204
Internet: kevin@ims.alaska.edu
Telex: 7402055 SFOS UC
Omnet: ALASKA.INST

Dr. David Eslinger, Assistant Professor
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-7797
Fax: 907-474-7204
Internet: eslinger@ims.alaska.edu
Telex: 7402055 SFOS UC
Omnet: D.ESLINGER

Dr. Elena Filimonova, Associate Director
International Department
Far Eastern State University
ul. Sukhanova 8
690600 Vladivostock, Russia
Fax: 7-4232-257200
Telex: 213218 FESU SU

Dr. Miguel D. Fortes, Professor
Marine Science Institute
University of the Philippines
Diliman 1101
Quezon City, Philippines
Phone: 632-989676 ext. 7414
Fax: 632-924-3735
Telex: 2231 UP DIL PU MSI

Mr. Terry Gacke, Technician
Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, AK 99775-7260 USA
Phone: 907-474-5585
Fax: 907-474-5582
Omnet: PICO.UAF

Dr. John Goering, Associate Director
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-7895
Fax: 907-474-7204
Internet: ffjjg@aurora.alaska.edu
Telex: 7402055 SFOS UC
Omnet: J.GOERING

Prof. Praskovya Gogoleva, Chair
Department of Ecology
Yakutsk State University
ul. Belinskaya 58
677891 Republic Sakha (Yakutia) Yakutsk, Russia
Phone: 7-095-61092
Fax: 7-095-230-2929
Telex: 145126 LENA SU

Dr. Raymond Highsmith, Director
West Coast National Underwater Research Center
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-5874
Fax: 907-474-5804
Internet: ffrch1@aurora.alaska.edu
Telex: 7402055 SFOS UC
Omnet: R.HIGHSMITH

Professor Manuwadi Hungspreugs
Department of Marine Science
Chulalongkorn University
Phyathai Road
Bangkok 10330 Thailand
Phone: 662-251-6968
Fax: 662-251-1951

Prof. Viktor Ilyichev, Director
Pacific Oceanological Institute
Far Eastern Branch
Russian Academy of Sciences
ul. Baltiskaya 43
690041 Vladivostock, Russia
Phone: 7-4232-310666
Fax: 7-4232-224552
Internet: dva@adonis.ias.msk.su
Telex: 213238 DALPA

Dr. Aldona Jonaitis, Director
University of Alaska Museum
University of Alaska Fairbanks
Fairbanks, AK 99775-6960 USA
Phone: 907-474-7505
Fax: 907-474-5469

Dr. Mamoru Kawazoe
Associate Executive Director
Research Development Bureau
Tokai University Educational System
2-28-4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3467-2211
Fax: 81-3-3460-4515

Dr. Yury Kazakov, Director
Department of International Cooperation
Ministry of Protection of the Environment and Natural Resources
ul. B. Gruzinskaya 4/6
123812 Moscow, Russia
Phone: 7 (095) 254 4638
Fax: 7 (095) 254 8283
Telex: 411692 BOREI SU

Dr. John Kelley, Director
Polar Ice Coring Office
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7260 USA
Phone: 907-474-5585
Fax: 907-474-5582
Omnet: PICO.UAF

President Jerome B. Komisar
University of Alaska
Fairbanks, AK 99775-5000 USA
Phone: 907-474-7311
Fax: 907-474-7570

Prof. Nadezhda Khristophorova, Chair
Ecology Department
Far Eastern State University
ul. Sukhanova 8
690600 Vladivostock, Russia
Fax: 7-4232-257200
Telex: 213218 FESU SU

Vladimir Kurilov, President
Far Eastern State University
ul. Sukhanova 8
690600 Vladivostock, Russia
Phone: 7-4232-261280
Fax: 7-4232-257200
Telex: 213218 FESU SU

Dr. Kosan Kusamran
Vice Rector for International Affairs
King Mongkut's Institute of Technology
Ladkrabang
Chulongkrung Road,
Ladkrabang District
Bangkok 10520 Thailand
Phone: 66-2-326-9157
Fax: 66-2-326-7333
Telex: 84967 INSMONG TH

Dr. Paul LeBlond, Professor
Department of Oceanography
University of British Columbia
6270 University Boulevard
Vancouver, BC V6T 1Z4 Canada
Phone: 604-822-2496
Fax: 604-822-6091
Internet: p_leblond@mtsg.ubc.ca
Omnet: P.LEBLOND

Dr. Fucheng Li, Visiting Scientist
Institute of Marine Science
Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, AK 99775-7260 USA
Phone: 907-474-5585
Fax: 907-474-5582
Omnet: PICO.UAF

President Tatsuro Matsumae
Tokai University Educational System
2-28-4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3467-2211
Fax: 81-3-3469-7992

President Kimikazu Matsuyama
Kyushu Tokai University
9-1-1, Toroku, Kumamoto-shi
Kumamoto 862 Japan
Phone: 81-96-382-1141
Fax: 81-96-382-015

Ms. Susan McNeil
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-5926
Fax: 907-474-7204
Telex: 7402055 SFOS UC
Omnet: ALASKA.INST

Mr. Larry Merculieff, City Manager
City of St. Paul
P.O. Box 9001
St. Paul Island, AK 99660 USA
Phone: 907-546-2331
Fax: 907-546-2365

President Yoshio Mihara
Hokkaido Tokai University
5–1–1–1 Minamisawa, Minami-ku
Sapporo, Hokkaido 005 Japan
Phone: 81-11-571-5111
Fax: 81-11-571-6903

Ms. Nina Mollett
Department of Natural Resources
University of Alaska Fairbanks
Fairbanks, AK 99775-7000 USA
Phone: 907-474-7768
Fax: 907-474-7439
Internet: ftndm@aurora.alaska.edu

Dr. Vijay Naidu, Pro Vice-Chancellor
University of the South Pacific
POB 1168
Suva, Fiji
Phone: 679-313900 ext. 2053
Fax: 679-302809
Telex: 2276 USP FJ

Professor Shiro Okabe
School of Marine Science and Technology
Tokai University
3-20-1. Orido, Shimizu-shi
Shizuoka 424 Japan
Phone: 81-543-34-0411
Fax: 81-543-34-0937

Prof. Valery Petrosyan, Rector
Open Ecological University, Professor
Department of Chemistry
Moscow State University
Leninskie Gory
119899 Moscow, Russia
Phone: 7-095-939 5643
Fax: 7-095-939 5546
Internet: petros@organic.chem.msu.su
Telex: 411483 MGU SU

Dr. Tony Pitcher, Director
Fisheries Centre
University of British Columbia
Vancouver, BC V6T 1W5 Canada
Phone: 604-822-2731
Fax: 604-822-8934

Dr. Carol Reinisch, Chair
Department of Comparative Medicine
Tufts Veterinary School
200 Westboro Road
North Grafton, MA 01536 USA
Phone: 508-839-7949
Fax: 508-839-7948

Prof. Toshibumi Sakata, Director
Research and Information Center
Tokai University
2–28–4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3481-0611
Fax: 81-3-3481-0610
Internet: 2423402 UNITOK J

Dr. Masanori Sakurai, Vice President
Dohto University
149, Nakanosawa, Hiroshima-cho
Sapporo-gun, Hokkaido Japan
Phone: 011-372-3111
Fax: 011-372-3542

Dr. Tsuneo Sato, Head
Social Work Class
Dohto University
149, Nakanosawa, Hiroshima-cho
Sapporo-gun, Hokkaido Japan
Phone: 011-372-3111
Fax: 011-372-3542

Dr. David Shaw, Professor
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220 USA
Phone: 907-474-7723
Fax: 907-474-7204
Internet: ffdgs@aurora.alaska.edu
Telex: 7408681 SHAW
Omnet: D.SHAW

Professor Haruhisa Shimoda
School of Engineering
Tokai University
1117, Kitakaname, Hiratsuka-shi
Kanagawa 259-12 Japan
Phone: 81-463-58-1211
Fax: 81-463-35-2456

Ms. Sherri Smith
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775-7000 USA
Phone: 907-474-7029
Fax: 907-474-6967
Internet: ftslt1@aurora.alaska.edu

Dr. Valery Stepanov, Assistant Professor
Department of Physics Theory
Yakutsk State University
ul. Belinskaya 58
677891 Republic Sakha (Yakutia) Yakutsk, Russia
Phone: 7-095-61092
Fax: 7-095-230-2929
Telex: 145126 LENA SU

Dr. William Stringer, Professor
Geophysical Institute
University of Alaska Fairbanks
Fairbanks, AK 99775-7320 USA
Phone: 907-474-7455
Fax: 907-474-7290
Omnet: GEOPH.INST.FBK

Prof. José Stuardo, Director
Department of Oceanography
Universidad de Concepción
Casilla 2407, Correo 10
Concepción, Chile
Phone: 56-41-234985 ext. 2502
Fax: 56-41-242546
Internet: jstuardo@halcon.dpi.udec.cl

Professor Yasuhiro Sugimori
School of Marine Science and Technology
Tokai University
3-20-1. Orido, Shimizu-shi
Shizuoka 424 Japan
Phone: 81-543-34-0411
Fax: 81-543-35-4155

Dr. Mariya Tayurskaya, Senior Lecturer
Department of Foreign Languages
Yakutsk State University
ul. Belinskaya 58
677891 Republic Sakha (Yakutia) Yakutsk, Russia
Phone: 7-095-61092
Fax: 7-095-230-2929
Telex: 145126 LENA SU

Professor Oktavii Tolstikhin
Department of Ecology
Yakutsk State University
ul. Belinskaya 58
677891 Republic Sakha (Yakutia) Yakutsk, Russia
Phone: 7-095-61092
Fax: 7-095-230-2929
Telex: 145126 LENA SU

President Thomas Trotter
Alaska Pacific University
4101 University Drive
Anchorage, AK 99508 USA
Phone: 907-564-8220
Fax: 907-562-4276

Professor Hirohisa Uchida
School of Engineering
Tokai University
1117, Kitakaname, Hiratsuka-shi
Kanagawa 259-12 Japan
Phone: 81-463-58-1211
Fax: 81-463-58-1812

Dr. Juha Uitto, Academic Officer
The United Nations University
5-53-70, Jingumae, Shibuya-ku
Tokyo 150 Japan
Phone: 81-3-3499-2811
Fax: 81-3-3499-2828
Telex: 25442 J

Dr. Leandro Viloria, Professor
School of Urban and Regional Planning
University of the Philippines
Diliman
Quezon City 1101 Philippines
Phone: 632-971637
Fax: 632-983595

Mr. Takashi Watanabe, Section Chief
International Division
Tokai University Educational System
2-28-4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3469-6709
Fax: 81-3-3467-0197

Dr. Robert White, Director
Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775-7000 USA
Phone: 907-474-7648
Fax: 907-474-6967
Internet: ffrgw@aurora.alaska.edu

Professor Warren Wooster
School of Marine Affairs HF–05
University of Washington
Seattle, WA 98195 USA
Phone: 206-685-2497
Fax: 206-543-1417
Omnet: W.WOOSTER

Prof. Xu Mingzhi, Vice President
Fudan University
220 Handan Road
Shanghai 200433
China
Phone: 86-21-549-1128
Fax: 86-21-3989843

Mr. Nguyen Si Xung, Assistant Director-General
Institute for International Relations
Hanoi, Vietnam
Phone: 84-4-44194
Fax: 84-4-343543

Dr. Kiyoshi Yamada, Assistant Professor
School of Humanities and Culture
Tokai University
1117, Kitakaname, Hiratsuka-shi
Kanagawa 259-12 Japan
Phone: 81-463-58-1211
Fax: 81-463-35-2456

Dr. Supachai Yavaprabhas, Associate Professor
Office of International Affairs
Chulalongkorn University
Phyathai Road
Bangkok 10330 Thailand
Phone: 662-215-3648
Fax: 662-216-1299

Ms. Teiko Yokohata
International Division
Tokai University Educational System
2-28-4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3469-6709
Fax: 81-3-3467-0197

Dr. Shoji Yoshida, Director General
Research Development Bureau
Tokai University Educational System
2-28-4 Tomigaya, Shibuya-ku
Tokyo 151 Japan
Phone: 81-3-3467-2211
Fax: 81-3-3485-4959

Dr. David Yount
Vice President for Research and Graduate Education
University of Hawaii at Manoa
2444 Dole Street
Honolulu, HI 96822 USA
Phone: 808-956-7651
Fax: 808-956-9797

Prof. Valery Zautkin, First Vice President
Far Eastern State Technical University
ul. Pushkinskaya 10
690600 Vladivostock, Russia
Phone: 7-4232-265558
Fax: 7-4232-266988
Internet: root@dpicnit.marine.su
Telex: 213202 PTECH SU