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
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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.

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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


GF798.097 1993

ISBN 1-56612-027-6

doi:10.4027/ocsocc.1993
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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 Tokyo 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
Resources from the Pacific

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/km², 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 through 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 pollack.

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).](image-url)
Table 1. Principal fishery resources of the Pacific listed by FAO statistical area.

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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
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 clupeid discussed above). The roles and relative extent of primary producers, plankton consumers, predators, and detrivores 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

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**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).
Enrichment. Directional Changes: Global Warming and Nutrient change may produce an unequivocal shift in state. The linkage is not understood. In contrast to the system has switched from fish to jellyfish; but despite several recent conferences on the subject, swimming energetics; but despite

species will be replaced with unsuitable species; hence, changes that will impact humans the most, a litany 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 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 salmon—but 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 subserves 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 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 oceamic 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 fisheries 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 com-
munities have become aware of the economic
consequences of sectoral conflict.

Key elements in co-management are: direct in-
volve ment 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 per-
ceived gain.

Implementing this beneficial system becomes
more difficult the larger and more industrialized
the fishery resource. In both the developed and de-
veloping 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 communi-
ties 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 eco-

nomic activity is illegal and corrupt throughout the
world and that this will have an impact on our fish-
ery resources.

So our critical ignorance here is of processes
that can encourage successful cooperative manage-
ment. 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 igno-
rance 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 fo-
cused 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 rela-
tively few political divisions and ecological areas,
like the Humboldt current system, would be rela-
tively 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 har-
vests 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) to-
ward goals that better reflect whether the underly-
ing biomass of the resource is sufficiently abundant
to replace itself in the face of likely environmental
fluctuations in carrying capacity. Currently, fisher-
ies 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 fisher-
ies. But it has now been severely shaken by the
unexpected and complete collapse of the Newfound-
land cod stocks. These stocks had been managed by
Canadian fishery scientists using the most sophis-
ticated numerical methodology available. The spot-
light is now on independent methods of estimating
fish abundance such as experimental surveys and
acoustic methods. Estimations based on such inde-
pendent 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 em-
ploy super-scale models such as those used by me-
teorologists 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


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 untired. 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 breast bones 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 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 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, Chiloé 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

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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 equaled 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 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:

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

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:

\[ \begin{align*}
    x_t &= g(x_{t-1}, x_{t-2}, \ldots) - m_{t-1} - p_{t-1} + r_{t-1} - h_{t-1}.
\end{align*} \]

Biomass \((x_t)\) is a function of lagged biomass and physical-oceanographic factors such as temperature and salinity through the growth function \(g(\cdot)\), 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:

\[ \begin{align*}
    \begin{pmatrix} m_t \\ p_t \\ r_t \end{pmatrix} &= f(x_{t-1}, x_{t-2}, \ldots) \\
    \end{pmatrix} \]

where the vector valued function \( f \) 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:

\[ \begin{align*}
    x_t &= g(x_{t-1}, x_{t-2}, \ldots) - m(x_{t-1}, x_{t-2}, \ldots) \\
    \end{align*} \]

(4)

\[ \begin{align*}
    -p(x_{t-1}, x_{t-2}, \ldots) + r(x_{t-1}, x_{t-2}, \ldots) - h_{t-1} \\
    \end{align*} \]

where the function \( f \) has been implicitly redefined.

To use the model in equation (4), the form of \( f \) must be explicitly assumed, a priori. One of the simplest specifications of \( f \) 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:

\[ \begin{align*}
    x_t &= (1+g)x_{t-1} - \frac{g}{k}x_{t-1}^2 - h_{t-1} \\
    \end{align*} \]

(5)

\[ \begin{align*}
    = \beta_1 x_{t-1} - \beta_2 x_{t-1}^2 - h_{t-1} \\
    \end{align*} \]
where $g$ and $k$ are the intrinsic growth rate and carrying capacity, and $\beta_1$ and $\beta_2$ are implicitly defined. The estimated model is:

$$x_t = 1.461x_{t-1} - 0.0008x_{t-1}^2 - h_{t-1}$$

$$F(1.55) = 1,090.2.$$  

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

$$h_{SY} = 0.461x - 0.0008x^2.$$  

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

$$e_t = 6.68h_t^{1.279}x_t^{-1.518}$$

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:

$$TC_t = 100e_t + 193.02e_t = 293.02e_t.$$  

**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.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Maximum sustainable yield</th>
<th>Open access</th>
<th>Maximum economic yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1974–92</td>
<td>Low cost</td>
<td>Baseline</td>
<td>High price</td>
</tr>
<tr>
<td>Effort (million skates)</td>
<td>0.18</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>Total cost (millions, $U.S.)</td>
<td>$53.9</td>
<td>26.2</td>
<td>77.1</td>
<td>77.1</td>
</tr>
<tr>
<td>Catch (million pounds)</td>
<td>42.9</td>
<td>67.6</td>
<td>67.6</td>
<td>67.6</td>
</tr>
<tr>
<td>Price (U.S. $)</td>
<td>$1.37</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Total revenue (millions, $U.S.)</td>
<td>$53.9</td>
<td>47.5</td>
<td>47.5</td>
<td>115.1</td>
</tr>
<tr>
<td>Profit (millions, $U.S.)</td>
<td>$0.0</td>
<td>21.4</td>
<td>–29.5</td>
<td>38.4</td>
</tr>
<tr>
<td>Biomass (million pounds)</td>
<td>247.2</td>
<td>293</td>
<td>293</td>
<td>293</td>
</tr>
</tbody>
</table>
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 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**


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**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.