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Ad Mare: Canada Looks to the Sea

A Study on Marine Science and Technology

By R. W. Stewart and
L. M. Dickie

Ad Mare: Canada Looks to the Sea

A Study on Marine Science and Technology in Canada

The Canadian motto is *a mari usque ad mare*. The vision it usually evokes is that of the great and varied land mass between the seas. In this report, Canadians are challenged to see their coasts, not as a border, but as a springboard from which they can move out to seize the opportunities and meet the responsibilities of being a maritime nation.

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As authors of this report, it is our pleasure to acknowledge the friendly co-operation and willing assistance of the staff of the Science Council office in Ottawa. In particular we wish to express our warm feelings toward Dr. Roger D. Voyer, who was project officer for this study. Roger has worked closely with us throughout. He embodies a combination of the best features of Canada's two official cultures, and has contributed immeasurably to making an experience which might well have been tedious–even intolerable–into one which was always interesting and was often enjoyable.

During the course of this study we, together with Dr. Voyer, visited most of the cities in Canada in which marine science and technology activities are centred. We have conducted public panel discussions, and many private interviews and discussions with staff of government, university and industry establishments. We have viewed equipment and facilities and learned of hopes and ambitions in eight of Canada's ten provinces. All this was made possible and pleasant by the work and willing co-operation of many individuals. They are so many that we cannot possibly name them all here. However, we feel a special debt to a number who made particular efforts to ensure that we gained an overall appreciation of the situation as it exists in Canada today.

We gratefully acknowledge the expert economic advice given to us by M. Marcel Daneau, directeur, département des Sciences économiques, Université Laval, Québec.

We are especially grateful to Mr. Bruce Woodland at the Memorial University of Newfoundland, Dr. A.R.A. Taylor, Biology Department, University of New Brunswick, Dr. W.L. Ford, Director of the Atlantic Oceanographic Laboratory in the Bedford Institute, Dr. J.A. Blanchard of the Nova Scotia Research Foundation, Mr. A.E. Pallister of Pallister Associates in Calgary, Dr. W.N. English of the B.C. Research Council and Dr. H.L. Grant of the Defence Research Establishment Pacific, all of whom organized public panel discussions for us. The panelists and audiences at these discussions contributed many ideas and much information which were of great value in preparation of the report.

Industry representatives, government employees and university staff and students have submitted written briefs and statements to us, some of them in direct response to our requests. We wish especially to acknowledge the contributions of Mr. C. MacLaughlin of Montreal Engineering in Montreal, Mr. T. Horton of International Hydrodynamics in Vancouver, Mr. W. Zaruby, Shell Oil in Calgary, Mr. F. Misner, Garrett Marine in Toronto, Messrs. M. Colpitts and R. Krajewski of the Department of Industry, Trade and Commerce, and Mr. T. Harwood, Chairman of the Working Group on Ice in Navigable Waters, all of whom discussed various aspects of our work with us. While we have not always agreed with them, their contributions have been essential to giving us an appreciation of a complex field, many aspects of which were unfamiliar to us.

We cannot pass up this opportunity to say that at times during our work we were sometimes led to conclude that there is a brilliant future for marine science and technology in Canada, if only more Canadians and foreign visitors could savour the excellent seafood dinners we were served. The variety of seafood delicacies served to us by the co-operative efforts of staff, students and the people of Bamfield on Vancouver Island will always remain a highlight of our gastronomic experiences. Our experiences in some small restaurants in Victoria, B.C., Quebec City and St. John's, Newfoundland, were equally delightful. There was something especially satisfying about these concrete reminders that aspects of the subject of our study can affect our lives and attitudes in such real and personal ways. From our point of view, it is perhaps just as well that our study was not totally concerned with marine pollution!

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Preamble

Marine science, with its associated technology, differs in a fundamental way from such disciplines as physics, chemistry and biology; marine science, along with the technologies which have sprung from it, owes its existence as an entity not to an agreed body of knowledge but to the presence of a particular environment. Thus it has more in common with space science and technology than with any other contemporary discipline. It is the archetype of the interdisciplinary science. Except for some features of its biological aspect, it is also very new–so new that it is unwise to attempt to foresee the future as a simple extrapolation from the recent past. Thus physical oceanography is only now beginning to advance beyond a primitive state. Even an introductory discussion of marine geophysics would contain few concepts and very little data more than ten years old. Marine ecology is a recent offshoot of ecology, which itself has only developed beyond the pioneering stage since the Second World War. Other aspects of the science are hardly out of their infancy. As for marine technology, it is almost certain that the next decade will see more accomplished than the total up to the present. On the whole, then, marine science and technology are on the rapidly rising portion of a growth curve. Both the opportunities and the challenges are immense.

The nature of the challenges and the importance of response to them are highlighted by a new phenomenon which no previous civilization has ever had to consider: that man is making major alterations to the character of the earth. Of course man's activities have always affected his environment. Even quite primitive cultures were able to make deserts from productive land, and productive land from deserts. What is new is the scale and pace of activities and man's own recognition of the compexity and interconnectedness of the global ecosystem. Thus, while it is recognized that mining and smelting operations at Sudbury or at Trail can desolate the country for a few miles, or that irrigation can make green the barren areas of southern Alberta and the Okanagan Valley, it has been generally felt–more subconsciously than consciously–that both the atmosphere and the ocean as a whole are too large for a creature as puny as man to influence them importantly.

Only recently has it been recognized that this attitude is ill-founded. Products passed into the atmosphere are detectably changing its composition. Aerosols, mostly derived from industrial activity, can no longer be considered to be the concern only of such cities as Manchester and Hamilton, but are detectable over the whole earth and have an impact on the transmission of solar energy to the earth's surface. The quantity of carbon dioxide in the atmosphere seems to be increasing by two or three parts per thousand every year–affecting not only the radiation balance, but perhaps the acidity of the upper waters of the ocean as well. Lead entering the ocean from the atmosphere, and originating mostly from anti-knock compounds in gasoline, has increased the lead concentrations in the upper ocean by an order of magnitude. Heavy oil escaping into the ocean from a variety of sources is becoming unpleasantly noticeable, not only on beaches but in mid-ocean. Various pesticides concentrated by organisms are detectable throughout the oceans–including the Arctic and Antarctic. Dams constructed for power, irrigation and flood control alter runoff patterns and affect the salinity of some oceanic areas–thence their stability and mixing properties. Man's activities have long determined the nature of the major fauna and flora on land; now that fishing fleets range the whole of the oceans, and the intensity of fishing is very great, the same is becoming true of the oceans. Great engineering works have changed the face of the land. Large artificial lakes have been formed. Areas of swamp have been drained. The vegetation cover of a large fraction of the earth has been altered. All of these affect the atmosphere and to some extent the sea. We are now within sight of engineering works which would directly affect the ocean. Proposals have been made, particularly within the Soviet Union, for damming the Bering Strait with the purpose of reducing the ice cover of the Arctic. Other proposals have been made for inducing artificial up-wellings in the ocean in order to increase biological productivity. Such changes could have worldwide effects of far from negligible magnitude.

As is attested by the significant climatological fluctuations that have occurred in historical times, and the even more striking changes that produced and accompanied the great ice ages, the ocean-atmosphere system is not a particularly stable one and is subject to great fluctuations even without man's interference. Such is the present magnitude of man's influence that he is probably able to affect these overwhelmingly important and far-flung events.

We are now changing our environment and will continue to change it. That is not our choice. Our choice is whether we will change it blindly and perhaps disastrously, or change it intelligently with full realization of the probable impact of these changes. To offer an extreme example: damming the Bering Strait to reduce greatly the ice cover of the Arctic could, as its advocates believe, lead to a very great amelioration of the climate of Siberia and northern Canada. It could, however, according to the respected theory of Ewing and Donn[1], lead to a new ice age. It could, on the other hand, lead to the melting of the Greenland ice cap and to widespread coastal flooding. The Bering Strait *could* be considered to be the concern only of the neighbouring countries, the United States and the Soviet Union. To dam it is within contemporary engineering capability. What if they should decide to do so? The effects, good or bad, on Canada would be very large. Yet only through the possession of a respected and capable scientific group, able to anticipate what these effects would be, would Canada be in a position to exert any influence upon the decision.

This example is extreme, but not imaginary. A perhaps more immediate one is the management of the fishery off Canada's Atlantic Provinces. Beyond the limits of Canadian jurisdiction, this is an international fishery, but contemporary international law gives Canada a large degree of responsibility. Intelligent management to ensure both a high level of productivity in the area and a strong Canadian participation in the fishery demands real understanding of all aspects of the ecology. A similar statement can be made of the west coast fisheries. As another, and again somewhat different, example we might ask what is acceptable in the nature and quantity of industrial and residential effluent before the waters of the Strait of Georgia become endangered? Additional examples could be added almost endlessly.

What we find here in marine science and technology is a clear confluence of three principal motives which drive cultural and scientific change: satisfaction of the natural curiosity to understand the universe we inhabit; the desire to use the environment to promote our sense of comfort and well-being; and the recognition of an obligation to prevent irreparable damage to that environment.

The first motive, that of satisfying our curiosity, takes many forms, ranging from a layman's casual interest to a scientist's intense personal drive "to know". It has provided the challenge underlying all science and has been responsible for most of the ideas, the technical exploitation of which characterizes our civilization. In the guise of basic science, its pursuit is vociferously defended by the scientific community, almost as a "right"; and it is one of the large problems of modern society to decide how much of this basic science is need and how much is luxury.

[1]Ewing, Maurice and William L. Donn. A theory of ice ages. Science, 123(3207): 1061–1066. June 15, 1956.

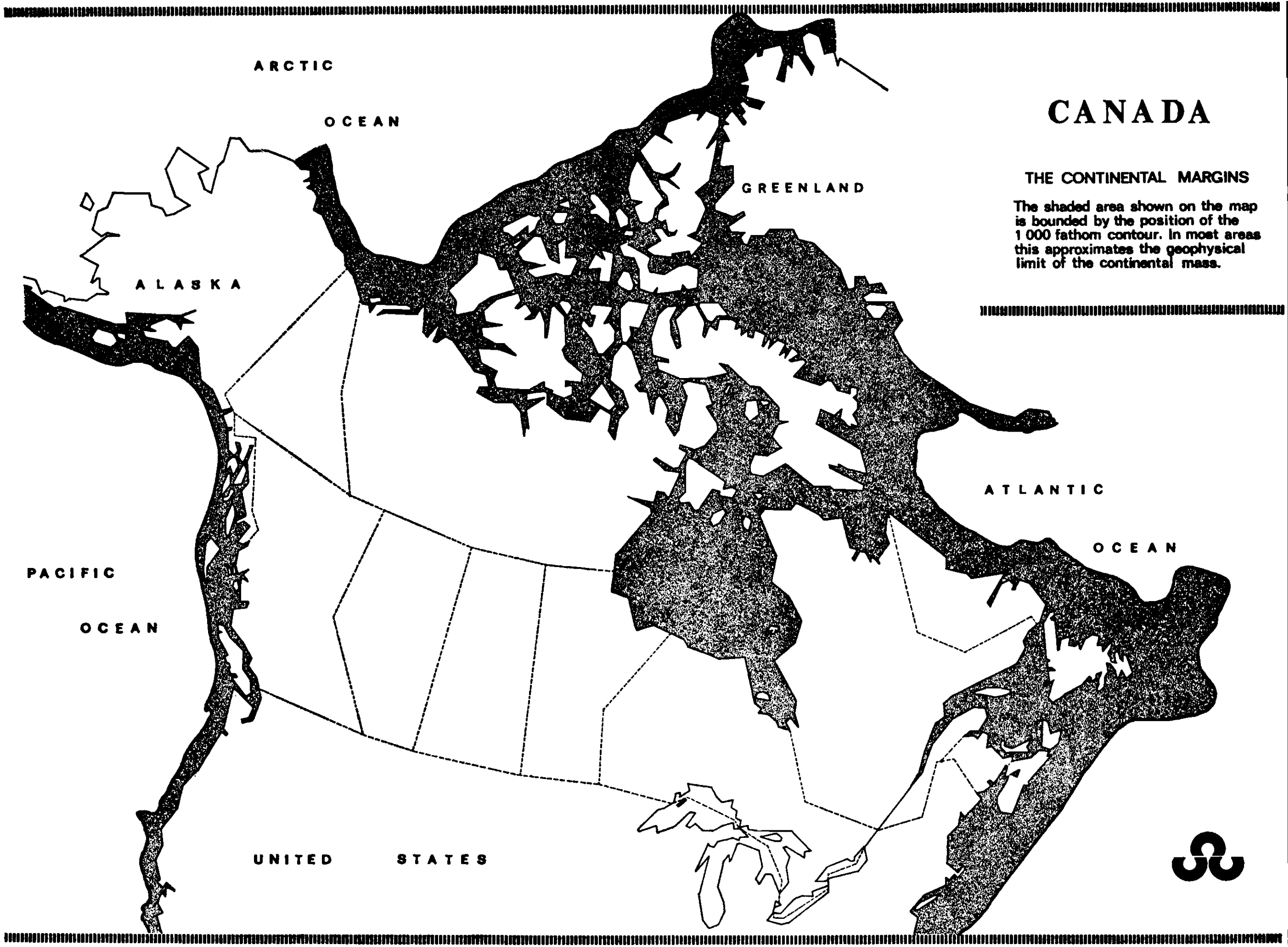
In this report we attempt to deal briefly with the marine aspects of this problem.

There is little doubt that the new knowledge which leads us to see opportunities for use and exploitation of the environment provides an especially strong motive to increase that knowledge. In this area, the strength of motives for doing marine science and technology has increased enormously in the past ten years. Technological advance has given added assurance that we can find ways to cope with the gigantic forces exerted by wind, waves, great depth and ice. At the same time, improved methods of inventory show that estimates of resources, considered as wild speculation ten years ago, now sound like solid potential. Wealth is to be won from the marine environment, stimulating challenges are to be met in the winning, and rich rewards will accrue to the winners.

In the past marine science, in common with world science, focussed its attention on the simpler, easier done things. There is nothing wrong with doing simple things. And in a complex environment, with too little knowledge, perhaps we have needed the reassurance that there are at least some things we can do. The approach through the simple has been necessary to our morale. But the big problems are still there and more than ever, and with our new knowledge we must face them squarely. We can no longer avoid challenges by diverting our attention and efforts to the easily attainable. The task is all the greater because of our responsibility to see that the challenges are met by Canadians, and that Canadians reap their full share of the rewards. This will require action, not accident, even for the resources in and over our continental shelves.

For Canada, the impact of marine exploitation on regional development gives it a special significance. The prospects for development are highest in those regions of the country that we currently regard as depressed or underdeveloped. Much of our report is necessarily addressed to the use of science and technology for promoting these possibilities.

The third motive–the need to understand–looms fully as large in our minds. The objective of any science is to raise understanding to the level that reliable predictions can be made. In this last third of the 20th century, nothing demands reliable prediction more than the effects of man's activities on his environment. There is thus a social need to develop high competence in the environmental sciences, a need which is independent of the usual "benefits" expected of scientific activities. It is our belief, expressed at various points in this report, that marine science is an essential facet of environmental science, and is to be developed and promoted as an essential part of our major responsibility for the control of environmental quality.


CANADA
THE CONTINENTAL MARGINS
The shaded area shown on the map is bounded by the position of the 1 000 fathom contour. In most areas this approximates the geophysical limit of the continental mass.
ARCTIC
OCEAN
GREENLAND
ALASKA
ATLANTIC
OCEAN
PACIFIC
OCEAN
UNITED STATES

Chapter I

Canada's Interest in the Sea

Depending upon how it is calculated, Canada has the longest or second longest coastline of any nation in the world. What might be called our submerged territory–those areas off our coasts which are geophysically continental but are below the surface of the ocean–comprises an area equal to over 40 per cent of our land area, equal in fact to the sum of Quebec, Ontario, Manitoba and Saskatchewan, or to that of all the territories combined. The potential productivity of these areas, both in renewable and non-renewable resources, is fully comparable to that of the corresponding land areas. Canada as a nation cannot afford to neglect them. To fail to assert full sovereign prerogatives with respect to the use and development of this potentially important part of the country would be to fail in our responsibilities to give future Canadians maximum possible opportunities for self-determination.

Canadian concern with the sea can be divided into a number of aspects:

1. It is a depot of resources.
2. It provides a recreational area.
3. It is an area which has commanded and will command an appreciable proportion of our defence effort; it is also an area where the limits of both sovereignty and jurisdiction are less clearly defined in legal and physical terms than elsewhere and so require more of our attention.
4. It is a medium of transportation.
5. It is of dominant importance in determining both weather and climate.
6. It is used, both intentionally and unintentionally, as a respository of waste materials; some of these constitute pollution.
7. It offers opportunities for the development of new technology and new industries.
8. It presents scientific challenges; the response to these challenges provides new knowledge and cultural inspiration.
9. It is an area in which aid to less-developed countries can be effective and in which Canada has an obligation to participate in international scientific ventures.

1. Resources

a) Biological

Of the sea's resources, the most valuable at present, both in Canada and in the world at large, are the fisheries. Although fisheries represent a rather small fraction of the total Canadian Gross National Product (GNP), they have high regional economic importance. In Nova Scotia, for example, they provide almost 10 per cent of the Gross Provincial Product, and this fraction is increasing. Nevertheless, the biological resources from the sea remain underexploited. On the west coast, the Canadian fishery remains concentrated on a very few species, and although other species are harvested by foreign operators, still others remain unexploited. While the catch of the Canadian east coast fishery is more varied, such known resources as capelin, argentines, and sand launce are hardly exploited at all.

Apart from fish and other large fauna, there are many organisms that offer opportunities of which little advantage has yet been taken. There is some harvesting of large algae in the Maritime Provinces, but since this material is exported in a virtually unprocessed state, its economic impact is small. The biomass of small zooplankton is much larger than that of the larger animals, and recent evidence indicates that these organisms may be concentrated much more intensely than was formerly thought, and new techniques may make exploitation possible. (Where the whales succeed, must we fail?) There is the possibility of utilizing biological materials, both flora and fauna, for use other than as food, for example in the development of pharmaceuticals. There are increasingly good prospects for economic estuarine and inshore culture of a number of marine organisms.

b) Petroleum Products

In the world as a whole, oil and gas is the second most important marine resource, after fisheries, now being exploited. At present, offshore oil production accounts for about 17 per cent of total "free world" production and is increasing at a rate of about 12 per cent per annum. As yet there is no production from the Canadian shelf. Nevertheless, the prospects are excellent. There is reason to believe that oil resources on the Canadian shelf exceed those of our land areas. Exploitation of these resources promises to produce in a few years economic activity amounting to several billion dollars a year.

The problems arising from the need to deal with oil and gas developments are so different from those arising from other marine activities, and are so urgent, that they are treated separately in Chapter II of this report.

c) Minerals

The continental shelves are geologically part of the continent and so can be expected to contain important mineral deposits. In addition, there are certain geological processes special to the sea which may provide exploitable concentrations. Wave action, either contemporary or ancient, produces sorting which leads to placer deposits. Rivers carry into the sea dissolved minerals which must be deposited somewhere. Dissolved materials, notably salt and magnesium, are now being extracted directly from sea water in various parts of the world. Chemical and biochemical processes can produce exploitable concentrations, such as those found in the so-called manganese nodules. In addition, the geophysical processes associated with ocean floor spreading and continental drift may produce concentrations as yet not recognized.

d) Water

The most plentiful material in the ocean is, of course, water. The production of fresh water by desalination processes may be regarded as competition for a resource of which we have prodigious quantities. This is not an *obvious* area for Canadian concentration. Nevertheless, expertise relevant to this problem may emerge either from novel concepts or as a by-product of other activities, for example pollution control. If so, this expertise can be exploited in other parts of the world either for sale or as an aspect of foreign aid.

2. Recreation

As populations become more affluent, and as the proportion of leisure time increases, recreation is providing a rapidly growing industry. Bodies of water are a central facet of very many kinds of recreational activity, so our coastal areas have an essential role to play. With the increasing demand for new and unusual experiences, even the Arctic can expect to share in this development. This is a "growth" industry, and efforts in this direction show promise of quick pay-off. They should be applied forcefully and imaginatively. It is particularly important, since many areas of the country which have few other resources and little prospect of industrial development are, or could be made, very attractive for recreational purposes.

3. Sovereignty and Defence

The magnitude and concentration of Canadian defence efforts involve matters of national policy beyond the terms of reference of this study. However, it is to be expected that there will be a continuing Canadian naval effort which will require both scientific and industrial backing.

There are other concerns apart from a purely military one. Canada has played, and must continue to play, an active role in international arrangements for regulating the exploitation of marine resources, within such bodies as the International Commission for the Northwest Atlantic Fisheries and the United Nations Committee on the Peaceful Uses of the Seabed Beyond the Limits of National Jurisdiction; only in this way can Canada ensure that its interests will be considered and its influence brought to bear on these arrangements, which are of vital importance to the country. Further, there is a need to maintain an adequate presence in certain areas of the Arctic. It may be necessary from time to time to redirect scientific and industrial activity in order to achieve these ends.

4. Transportation

On a world basis, the most financially rewarding use of the ocean is as a medium for transportation. In the last two decades the Canadian deep-sea Merchant Marine has dwindled to virtually nothing. This has been a matter of deliberate government policy, which has recognized that maintenance of a large ocean-going merchant fleet would require very large subsidies, and that most of the countries which supply our marine transportation are net importers from Canada. The question of the continuing applicability of this policy is the subject of a separate study[1] and we will not enter that debate. We have not taken our terms of reference as calling for an examination of problems concerning the construction and equipping of vessels for the Armed Forces or the Merchant Marine. Nevertheless, certain aspects of these problems have come to light in the course of the study, and when we consider them relevant, we feel free to comment.

Regardless of the decisions made concerning a Canadian deep-sea Merchant Marine, there remains some opportunity for Canada. Vessels specially suited to Canadian conditions on all three coasts are needed. So are special port facilities and all kinds of cargo-handling devices.

5. Weather and Climate

Contemporary weather forecasting methods increasingly recognize the impact of the ocean and its variability upon the weather. Such great international programs as the Global Atmospheric Research Program and the World Weather Watch take cognizance of the fact that improved weather forecasting calls for increased knowledge of the nature and response of the upper layers of the ocean.

[1]Water Transport Committee of the Canadian Transport Commission.

Apart from weather, which may be taken to be the short-term variability of the atmosphere, there are longer-term events even more dominated by the ocean. It is almost certain that such persistent phenomena as abnormally cold winters or extended periods of drought are associated with oceanic changes. With further research and better monitoring, they should become usefully predictable. Further, it is possible, at least for limited areas, to change the nature of the water surface by various kinds of engineering works. Thus they provide a technique for climate control, with very many ramifications. Such changes also occur naturally and as by-products of other human activities.

6. Pollution

Recent years have seen a very rapid rise in public awareness of the adverse effects that man can inflict upon his environment. The ocean, despite its great size, is not immune from these effects. There are several aspects under which pollution may be discussed.

a) Sewage

In sea water, sewage is objectionable chiefly for aesthetic reasons, although in some localities there can be eutrophication problems. There seems to be some tendency to exaggerate the sanitary aspects of sewage pollution in sea water. Unlike the situation in fresh water, there is little evidence of direct disease transmission associated with swimming in sea water.[2] The disease hazard seems to lie chiefly in the concentrations of microorganisms effected by certain molluscs.

b) Oil

Oil pollution is both aesthetically unpleasant, and damaging to a variety of marine organisms, as well as to many sea birds. It arises not just–or even chiefly–

[2]Sewage contamination of bathing beaches in England and Wales. Medical Research Council Memorandum No. 37, H.M. Stationery Office, London, 1959.

from spectacular accidents but from the myriad of small day-to-day fluxes occurring in the course of "normal" ship operations.

c) Industrial Pollutants

The effluents resulting from the various industrial processes have caused substantial damage to limited areas of the marine environment. Debris from pulp mills chokes several embayments. The elemental phosphorus released in the Placentia Bay disaster was both notorious and inexcusable. Not only must we avoid such disasters in the future, but public confidence must be restored so that there will be no outcry against the release of quite harmless effluent material.

d) Biochemical Pollutants

In contemporary life, we are making increasing use of materials whose principal characteristic is their dramatic biological effect even in minute concentrations. This is the characteristic that makes them useful. It is also a characteristic that makes them dangerous. DDT is an outstanding example. Others include weed killers and anti-foliants and the use of materials such as mercury. Particularly dangerous are those materials like DDT which persist for a very long time in the environment and are concentrated in the food chain.

7. Challenge to New Technology

As has already been indicated, marine science is on a rapidly rising portion of the growth curve. In Canada, marine technology has lagged somewhat and is only just reaching the point where expansion may be expected to be rapid. In the United States, there has been for the last few years an expectation that there would be a very large influx of government money into oceanography, comparable to that which supported the space program. Seeing that the space program was unlikely to grow much further, many companies of the aerospace industry began to look to oceanography as a source of further growth. However, the expected inflow of funds has not materialized and the U.S. industry is now in the throes of a "shake-out". The principal results of this flurry of activity have been to leave the United States with a substantial expertise in building and operating deep (and very expensive) submersibles and an ability to manufacture an assortment of oceanic buoys. By hindsight, it appears that the main source of their difficulty lay in a failure to associate many of the technological developments with any clearly defined need, and an ill-founded expectation that the combination of motives of national prestige, love of adventure, and scientific curiosity that has driven the U.S. space program would also provide multibillion-dollar support for the study of "inner space". Not having had such expectations, the Canadian industry has not seen a similar development and no such shake-out can be foreseen at present. The deep submersible *Pisces* has been developed in Canada. It is much more economical, and much more rentable, than its U.S. equivalents. Industrial expertise has also been developed in several other areas, generally with a clear market in view.

The scope of market opportunities is now expanding widely. Canada is in a very strong position to make a rapid but orderly growth in the marine technology field and to profit from observing the consequences of U.S. mistakes.

However, we are faced with a typically Canadian problem. Up to the present, the greatest activity in the marine field (apart from transportation) has been within government laboratories. A great deal of expertise has been developed within these laboratories to meet scientific requirements. Unfortunately, this expertise is not associated with any manufacturing capability. If we are to take advantage of that growth in marine activity which is surely to be expected, we must ensure that this information and expertise become available to the Canadian industry, and that this industry is enabled to grow rapidly as part of our national programs. This topic will be dealt with at length in Chapter VI of this report.

8. Cultural Inspiration and New Knowledge

In a report about marine science and technology, it is still worth remembering the simple fact that some men love the sea. It provides a fascination and challenge that has drawn most mariners to it. Given a chance–whether in the days of the magnificent wooden sailing ships of Nova Scotia or the great fleets of merchantmen and escorts during the war–Canadian mariners have shown that they can carry themselves with fortitude and serve their country with pride. Many men feel diminished when ashore. These things are hard to measure in economic terms. But it is certain that in our new marine ventures we need and will depend heavily on this special breed. Our future programs must have an eye to combining the nation's needs with the abilities of these men to realize their personal aspirations.

The motivations of the mariner have also led many scientists and some technologists to the sea; but the reasons for their staying are more often the intellectual and physical challenges of knowing about it and being able to do things in it. As a result, the quality of Canadian marine science is of very high international repute. Canadian marine scientists have been sought and employed as technical experts on a variety of international organizations. In such diverse fields as primary productivity, population dynamics, air-sea interaction, and geomagnetics, to identify but a few, Canadian efforts are recognized as being among the best in the world. Indeed, on a world scale, Canada's efforts in the marine sciences probably rate among the first four or five nations in both quantity and quality of work performed. On the whole, this performance has been achieved not because of the expenditure of vast sums, but rather because of the high quality of the personnel involved. Canadians have every right to be proud of these efforts, and the scientists who are carrying them out have every right to expect continued support.

The response that has been awarded to such people as Rachel Carson[1] and Jacques Cousteau shows that many members of the general public share an interest in the sea. Its very immensity and complexity provide an exciting challenge to many minds. Even if there were no prospect of economic return, and no social requirement for environmental information, the ocean would still be studied, although probably at a level that is less intense than is desirable in view of the rewards that are promised and the needs that must be met. However, it is fair to say that not enough Canadians have been involved in the activity of bringing the results of science before the public. In the environmental sciences particularly, they have a right to know, and an informed public opinion constitutes a substantial national asset. More effort could be expended in this direction–probably fruitfully. A deliberate program to enable skilled writers and photographers to become informed on environmental matters, and then to disseminate this information, is clearly indicated.

9. Foreign Aid and International Obligations

The responsibility of technologically advanced countries to assist those less developed is now well recognized. As has been pointed out, in the field of marine science, Canada is and will continue to be among the scientific leaders. Our technological abilities are appreciable, and should grow rapidly. The majority of the less-developed countries have marine responsibilities and we should be prepared to help them. There are several things we can do. We can provide assistance in making surveys, both hydrographical and of marine resources. We can be of assistance in the technology of their fishing fleets. We can help with the processing, transportation and distribution problems of marine products.

[1]We refer to such earlier works as *The Sea Around Us*, rather than the apocalyptic vision of *Silent Spring*.

Our technology, together with our experience as a capital-importing country which has undertaken a vast program of resource development under difficult conditions, could be of particular value to developing countries with respect to the development of their offshore resources. This represents a potentially rich area of mutual co-operation which should be carefully explored in the immediate future.

All these activities call on Canada to develop its marine science and technology with an eye to world problems, both by means of direct bilateral agreements and by participation in co-ordinated international aid schemes.

Beyond the social aspect of international programs, it must be remembered that neither ocean nor atmosphere respects political boundaries which divide men. Further, the scope of problems arising in both media is too great to be covered by the resources of any single nation–even the most wealthy. As a consequence, the growth of knowledge of meteorological and oceanographic systems, and of how to predict and make use of them, has become the subject of many co-operative internationally organized studies.

Not only do our land mass and the adjacent waters constitute a substantial fraction of the earth's surface, so that knowledge of them must be contributed to world studies, but the behaviour of atmosphere and ocean beyond our borders also affects many aspects of Canadian life. Their study must thus form an integral part of our national effort.

There are many such international programs. The World Weather Watch, the Global Atmosphere Research Program, and the International Biological Program are vigorous contemporary examples. Recently the North Atlantic Treaty Organization has formulated a number of studies of the "Challenges to Modern Society". Each of these programs has important oceanic components. The International Global Observing Station System has been slower to gather momentum, but this essentially oceanographic venture will unquestionably grow in importance in this decade.

These international programs call for use of some of our best scientific talents and affect the deployment of our physical facilities. That these activities play an important role in our total international endeavours is recognized by the creation within the Department of External Affairs of a special group devoted to Science Relations and Environmental Problems. In its future plans for marine science and technology in Canada, it is essential that government ensure that the staff and facilities of its operating agencies are sufficient to support strong Canadian participation. While it is unlikely that Canada can contribute on a scale commensurate with the fraction of the world's surface which our country and its adjacent seas comprise, it is certain that we have a responsibility to contribute and a need for new knowledge that are greater than our relative population size.

The compartmentalization used in the above listing is a totally artificial one and many important facets of marine science cut across these lines. For example, problems of pollution are intensely relevant both to recreational uses of marine areas and to fisheries. Since oil development leads to dangers of pollution, it also interacts. Activities in the defence field necessarily have a considerable impact upon marine technology. The scientific activity should interact strongly with all other areas. Thus the organizations that are designed to deal with marine science and technology[1] cannot have too sharp boundaries. Not only is the field interdisciplinary, but it will cut across almost any other conceivable compartmentalization. This clearly calls for considerable subtlety in constructing organizations to deal with marine science and technology. An attempt to handle these problems is made in Chapter VI.

[1]See definitions in Appendix A.

Summary of Study on Marine Science and Technology in Canada

During our study we were much impressed by the striking way the marine field of activities in Canada has changed in the past ten years. This is especially true because of the interest in offshore oil. In another ten years we must expect this to become a billion-dollar industry, exerting strong demands on marine science and technology for information and service, and requiring a large effort on the part of government to obtain the information and to develop the mechanisms it needs to ensure control and orderly development in the national interest. But even fisheries, often thought of popularly as representing some kind of social welfare and wealth redistribution mechanism, show local economic vigour. In these areas of vigour the growth rate for fisheries is considerably above that of national GNP, even if it is not as startling as the growth we expect soon to occur in areas associated with oil and gas. The knowledge we have gained also suggests several new fisheries aspects with large growth potential.

We did not deal directly with marine transportation problems in our study, but several important peripheral aspects concerned with research vessel building and operating programs, demonstration vessels and port facility designs are given attention. Defence aspects are treated only insofar as they affect or interact with the civil efforts. The effects of industry on the environment, and of man's general activities both on local conditions and on the larger scale conditions we comprehend under the general term "climate", are so great that we have found it necessary to consider these aspects in considerable detail. It is also increasingly apparent that Canada's own interests, as well as her responsibilities to contribute to increased welfare in the world generally, require that Canada give increased attention to participation in international marine science and technological activities. Altogether, the needs and opportunities in oil and gas, and fisheries and transportation, added to growing new demands in recreation, anti-pollution, and climatic prediction and control, have such a large impact on the Canadian scene as to require a serious reconsideration of the place of marine science and technology in our total national picture.

Considering these needs, we have concluded that a national marine development program should be quickly developed for the 1970s. It should consist of four major elements:

1. A deliberate policy to develop a major marine-oriented secondary industry in Canada, based on existing or newly encouraged marine science and technology and industrial expertise, to serve the potentially very large primary industry in offshore oil and gas, and the growing fisheries, recreation and pollution control industries.
2. A policy to develop legal and organizational mechanisms which would make marine activities effective instruments in the promulgation of both national and international policies.
3. A policy to develop marine science and technology as an integral part of the field of environmental science, required to ensure maintenance of a high-quality physical and social environment.
4. A policy to extend the definition of environmental quality control to include climatic change, by setting up programs to deliberately assess our capacity to affect climate and provide the knowledge needed to back up the national and international negotiations which environmental quality control implies.

Our review indicates to us that Canada is in an especially favourable position for developing the marine area as a special area for national effort, both because we have an excellent starting point in our scientific and educational institutions, and because there are ready large markets for our primary products. However, it is clear to us that our present organizational and administrative mechanisms are not sufficient to realize the opportunities or carry out the tasks. Nor is our present relative level of support of the overall activity sufficiently high.

We have concluded that a number of specific steps must be taken to institute an effective national program.

1. The federal government should immediately set up an advisory board, reporting to the minister responsible for science policy, to consider the merits of the kind of national program set out here as an objective for the 1970s and as a basis for formulating a national policy.

2. The federal government must take the initiative to develop a strong, technically self-reliant Canadian secondary industry by setting up a Canadian Ocean Development Corporation as a Crown Corporation, with major management as well as financial responsibility. It should be charged with undertaking the job of a systems manager in the development of a Canadian marine-oriented industry. By advice, persuasion and financial contracting it will:

a) initiate the manufacture of specific instruments and objects for Canadian and foreign markets;

b) encourage creation of a service industry and private consultants;

c) promote the development of R & D activities in industry;

d) take responsibility for promoting technology-transfer from government and industry laboratories to industry.

3. The federal government should revamp the administrative mechanisms and assignment of organizational responsibilities which it attempts to use to promote growth of scientific and technological knowledge and increased use by industry and government managers. A new organizational structure is proposed in Chapter VI. There are many separate points dealt with in the report, especially in Chapters V and VI.

Among others we see a need for:

a) studying methods for administering science as opposed to service, with a view to increasing the level of authority and accountability at the scientific operating levels (pp. 130-132);

b) integrating government research direction into top departmental management (pp. 130-131);

c) associating government and industry R & D at the operating level;

d) establishing a peripatetic information service for marine development (pp. 37, 115);

e) creating strong R & D competence in industry (pp. 101-103, 117-126, 132);

f) instituting stronger use of incentives to promote technology-transfer by contracting out, and increasing staff mobility (pp. 132-134);

g) re-examination of tariff and customs structures to remove penalties for Canadian business (pp. 34-35, 134-135);

h) extending principles of National Research Council grants for scientific excellence to the whole scientific community including government and industry (pp. 126-127);

i) separating grants for excellence by NRC from grants for "relevance" by government departments (p. 128);

j) stabilizing the demand for graduates so that universities can project the requirement five years in advance, and by flexible use of postdoctoral fellowships (pp. 95-96, 128-129);

k) relaxing the dependence of university research on production of graduates (pp. 94-97);

l) creating training programs for ocean engineers (pp. 97-98, 129-130);

m) preserving the best features of existing methods for co-ordinating programs and providing facilities (pp. 59, 60, 112-114, 135-143);

n) instituting emergency measures to deal with oil spills at sea (pp. 42, 73-75);

o) consolidating and improving government control of future pollution problems (pp. 75-77);

p) organizing and supporting increased activity in the Pacific and Arctic (pp. 142-144).

The requirements for a marine science and industry program are many and varied. Co-ordination is difficult, as is the means of giving a voice to the Canadian public for an evaluation of the programs.

As a means of achieving a focus, we urge the initiation of studies which could lead to the adoption of a series of four major projects. These are described briefly in pp. 38-41 and 104-106, and methods for administering them are dealt with in pp. 147-149.

Aside from the policies and programs which we believe should, indeed must, be developed as soon as possible in the 1970s, there are outstanding current needs to co-ordinate and control an orderly development of the offshore oil and gas industries. These industries already have considerable momentum, but the overlapping and sometimes conflicting *ad hoc* decisions in different government departments already show signs of either inhibiting the industry or permitting its control to pass out of Canadian hands. We therefore urge the immediate creation of an Interdepartmental Continental Shelf Committee of top government managers, possibly related to the Interdepartmental Committee on Resources. Some suggested problems and terms of reference are given in Chapter II, pp. 32-37.

To support the increased activities in the marine area will require an increase in the relative level of Canadian expenditure in marine science and technology in industry, government and university. From an analysis of the requirements and needs, we have built up what we believe to be a realistic projection based on the expected benefits. Our conclusion is that by 1980 the proportion of federal expenditures in support of scientific and industrial-type activity devoted to the marine area should be approximately double its present level. Details are given in Chapter VII.

Chapter II

The Offshore Search for Hydrocarbons

Opportunities and Special Responsibilities

The present situation with regard to exploration for oil and gas in offshore sediments is so very different from other aspects of Marine Science and Technology that it will be treated separately here. There are aspects that require extremely prompt government decisions, and others that require new structures capable of responding with flexibility and speed to rapidly changing developments.

Some concept of the immediacy and rate with which developments are occurring can be gained from the fact that between 1968 and 1969, the offshore area covered by federal permits for oil and gas development has increased from 217 million acres to 450 million acres. *Oilweek*[1] states that estimated industry expenditures on offshore exploration grew from $15 million in 1967 and $20 million in 1968[2] to about $25 million in 1969 and an expected minimum of $40 million in 1970. Over a 12-year period, work commitments on federal offshore permits amount to about $1.2 billion. The same issue of *Oilweek* notes that "given the first big offshore oil strike, these figures will represent but a modest start as outlays skyrocket".

Table II.1 shows the size of the potentialities. To convert into dollars, one barrel of oil is worth rather more than $2, and one million cubic feet of gas is worth rather more than $100. The potential offshore reserves of oil and gas are roughly half the total for all of Canada. Other estimates place this proportion much higher, and our impression is that the figures of the Canadian Petroleum Association used in Table II.1 are very conservative indeed. To put these figures into context, the rich Gulf Coast region offshore from Texas and Louisiana is thought to have recoverable reserves of less than 4 500 million barrels of oil and 50×10^{12} cubic feet of natural gas, i.e. about one tenth of the Canadian offshore potential. An Amoco brief to the Water Transport Committee[3] points out that in 1968 this Texas-Louisiana field produced over 900 000 barrels of oil and 5×10^9 cubic feet of gas daily from 5 452 oil wells and 1 735 gas wells. To put these figures further into context, Canadian production in 1966 averaged about 1 million barrels of oil and 4.2×10^9 cubic feet of gas daily.[4]

Offshore oil and gas, then, promise to yield developments at least as important as our existing petroleum-producing industry, and perhaps many times as big. About half of this promise arises from waters surrounding the Atlantic Provinces–that is, the region of Canada most in need of economic development.

There is a serious possibility that the petroleum industry will, in the course of a few years, have the same sort of dramatic impact upon the economic life of the Atlantic Provinces as it has already had on Alberta, since the populations are similar (2 million for the Atlantic Provinces against 1½ million for Alberta). As is pointed out by the Canadian Petroleum Association[5], it is difficult to measure this impact since it is so large that it significantly affects the size of the population itself. Subjectively, however, it is clear that everything–from the level of economic activity to the very image that the people have of themselves–has been modified by the development of the industry in Alberta.

Some estimates of the impact which this industry promises to have can be gained looking at further data concerning the American Gulf Coast, bearing in mind that Canadian offshore developments are expected eventually to be much larger–perhaps an order of magnitude larger.

According to the *Oil and Gas Journal*[6], in the spring of 1969 no fewer than 68 mobile

[1]Oilweek. May 12, 1969.

[2]For comparison, federal government expenditures on offshore geophysical work were about $5½ million in 1968.

[3]Submission of Amoco Canada Petroleum Limited to the Water Transport Committee of the Canadian Transport Commission. December 3, 1969.

[4]Canada Year Book, 1968.

[5]Submission to Minister of Finance on Carter Royal Commission on Taxation by the Canadian Petroleum Association. September 1967.

[6]Oil and Gas Journal. May 12, 1969.

Table II.1–Canada's Offshore Oil Potential

Region	Area	Sedimentary Volume	Oil Yield	Potential Oil Reserves	Potential Gas Reserves
	miles sq.	miles cu.	bbls. per miles cu.	10^6 bbls.	10^{12} cu. ft.
Arctic Offshore	250 000	450 000	55 000	24 750	148.5
East Coast	246 000	450 000	55 000	24 750	148.5
Gulf of St. Lawrence	94 000	145 000	15 000	2 175	10.9
Hudson Bay	365 000	145 000	20 000	2 900	17.4
West Coast	48 000	45 000	40 000	1 800	10.8
Total Offshore	**1 003 000**	**1 235 000**	–	**56 375**	**336.1**
Total All Canada	**2 057 000**	**2 641 500**	–	**120 805**	**724.8**

Source: Canadian Petroleum Association, except Arctic offshore, estimated by *Oilweek* based on CPA and other data.

exploratory drilling rigs were operating in the Gulf of Mexico. Of these, 30 were rated for water depths of over 100 feet. Each rig represents a multimillion-dollar investment. The Sedco rigs now being built in Halifax cost about $12 million each to construct, but that figure is appreciably higher than the average for the Gulf Coast because of the deeper water in the offshore Atlantic.

These rigs are for exploration. For exploitation one needs different structures. Considerations based on experience in Cook Inlet, Alaska, led to the following estimates[1] for construction of a production platform in 300 feet of water:

Steel required	9 000 tons (worth more than $100 a ton)
Installation time	45 days
Derrick barge construction and maintenance crews	82 men
Six tugboat crews of 11 men each	66 men
One crew boat	3 men
Total man-days of highly skilled labour	6 800 man-days

We have already noted that on the Gulf Coast there are over 7 000 producing wells offshore. Because of the more difficult conditions, Canadian wells will have to be more productive on the average to be economic, but the number remains relevant. The total work force directly involved in offshore activities on the Gulf Coast is estimated[2] at about 60 000, *not* including support activities such as warehousing, steel production, processing and stockpiling, and a host of others.

This is a billion-dollar business! It is clearly worth substantial investment in time and money to ensure that an appropriately high proportion of the business generated on the Canadian shelves–and in the world at large–falls to Canadians.

We noted above the impact which a perhaps smaller petroleum resource has had on Alberta. The Atlantic Provinces even have some advantages not shared by Alberta. The oil industry is a heavy consumer of steel. Not only does it use vast quantities of steel pipe and structural steel, but there are numerous tanks and fittings of all kinds. Unlike Alberta, Nova Scotia has a primary steel industry. In our opinion, it can find, in the oil business, expanded possibilities for a vertically integrated steelmaking complex. We believe that this industry should *now* be examining the prospects for the manufacture of drill pipe. Not only is it favourably sited for supplying all drilling operations in the Atlantic Provinces, but it should be in an equally favoured competitive position to supply operations in the whole of the eastern Arctic. The probability that something major will develop in at least one of these areas is so large that there is almost certain to be a Canadian market for such drilling pipe. Even in the unlikely chance that none of these hopes and expectations is realized, offshore activities are going on adjacent to some

[1]Private source.
[2]Private source.

70 countries in various parts of the world, and it is surely possible to find a market somewhere, even if at a somewhat less profitable figure than could be realized for deliveries to Canadian offshore and Arctic operations.

The oil industry brought prosperity to Alberta without much government intervention except for regulations concerning conservation and the control and sale of exploration and exploitation permits. At first, almost all personnel involved were from the United States, but over the years the local people have become more and more involved, until the industry is now largely manned by Canadians.

Cannot the same be expected to happen in the case of offshore oil? Our response to this question is: No! There *are* no local people offshore, and the business is necessarily conducted at long range. We believe that without Canadian Government intervention this range is likely to be extended so far that the base of many operations will be outside the country. The advantage gained by Canadians from the exploitation of their resources would then be far less than it should be. Not only must Canadian Government control be exercised over all matters concerning these offshore activities, but the regulations themselves must be designed so as to optimize the level of Canadian participation.

Figure II.1 shows how extensive and widespread offshore oil exploration areas are. Offshore oil permits have been issued almost everywhere on the Canadian shelves: off the west coast of Canada, within the "inland passage" waters on the west coast, in the Beaufort Sea, among the Arctic islands, in Hudson Bay, in the Gulf of St. Lawrence, on the Scotian shelf, on the Labrador shelf, on the Grand Banks and on Flemish Cap. Each area has its own problems and could be discussed separately. However, such detailed treatment is unwarranted in this report and, instead, we will group them into three areas with substantially different problems: the waters surrounding the Atlantic Provinces, the Arctic regions including Hudson Bay, and the west coast.

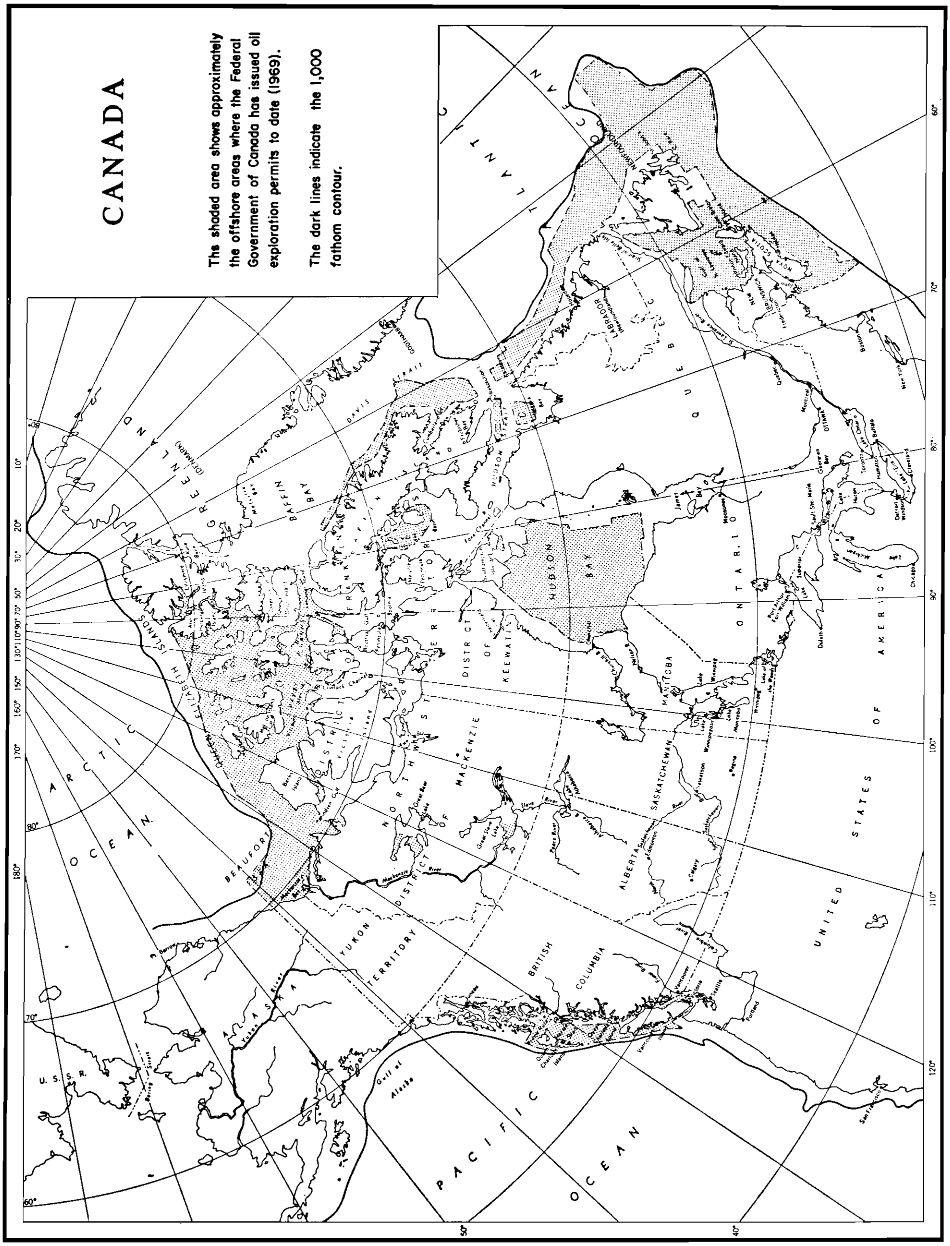
The Atlantic Area

Prospects for the discovery of oil and gas reserves on the shelf areas surrounding the Atlantic Provinces are excellent, and the potential is very large–so large, indeed, that one might be concerned about the availability of markets. We have not taken it that an investigation of market possibilities is part of the responsibility of the Study Group. We assume that since the industry is prepared to invest such large quantities of its own money, markets will be forthcoming. In any case, the industry expects ordinary demand growth to be about 8 per cent per year[1], a factor of over 2 in 10 years. The National Energy Board predicts[2] a fivefold increase in Canada's oil production by 1990–a virtually identical growth rate. This, coupled with the fact that about half of the oil refined in Canada is imported, may mean that marketing will not prove to be a major problem. Markets for gas are probably readily available in the United States.[3] If the much-discussed continental oil policy becomes a reality, access to the huge American market should resolve most marketing problems.

With present technology, offshore oil is significantly more expensive to develop than are comparable resources on land. Development will be economic only if large fields are discovered, but it is obviously the opinion of the industry that such will be the case. Work commitments on existing federal offshore permits call for the expenditure, in this Atlantic area alone, of about two thirds of a billion dollars over the next dozen years. As has been pointed out, if and when a strike is made, both the pace and the amount of the expenditure will increase greatly. By way of comparison, the total value added to the Canadian economy by fishing for food products is now of the order of $300 million a year.

[1]The Financial Post. December 13, 1969.
[2]Montreal Gazette 74th Business Review and Forecast. January 2, 1970.
[3]Oilweek. January 5, 1970.

Figure II.1–Offshore Oil Exploration Activity.



Thus even the average of $50 million or so per year, which will soon be spent under these commitments, represents a substantial industry *if enough of it can be made to accrue to the Canadian economy.*

One of the great human assets of the Canadian Atlantic Provinces is seamanship. At present it is somewhat underemployed, particularly in Newfoundland. To the extent possible, it should be required that shipping involved in the oil exploration and recovery business should use Canadian crews. The activity should also use Canadian vessels as fast as these can be made available. It is worth noting that the Amoco brief[1] quotes an estimate of 504 conventionally shaped boats used to service the Gulf Coast area in 1960. If this new activity results in a decrease in the manpower of ships available for the fisheries industry, so be it. Such a situation will, however, make necessary a much more rapid rationalization of the fishing industry (see Chapter IV). The overall result will be a more productive use of these valuable maritime skills.

There are a number of interlocking problems which will have to be faced in properly handling the opportunities that arise from this explosive growth of the petroleum industry on the east coast. Solutions to these problems concern a number of federal departments.

Care will have to be taken that there is no important adverse impact on the fishery. The Department of Fisheries and Forestry is therefore obviously involved.

The Department of Transport (DOT) has important duties to perform. It has the responsibility of administering the Canada Shipping Act. Decisions made by DOT on the application of regulations governing shipping can have tremendous influence on the activity. The department must act with great delicacy and intelligence, since these decisions can influence very strongly the economics of the whole operation and the degree of Canadian participation in it.

The Department of External Affairs is involved because the nature of jurisdiction of any country over the adjacent continental shelf is not yet clearly defined. The *ad hoc* decisions which must be made will have to take account of implications for future management and control.

The Department of Industry, Trade and Commerce (ITC) has a crucial role to play because of the need to encourage Canadian enterprise, and because of its knowledge of the capabilities and potentialities of the Canadian industry.

The Department of Regional Economic Expansion (REE) is deeply involved because the magnitude of the offshore oil industry is such that it will affect almost all other developments in the area. In addition, REE has views to express concerning industrial development, which derive from a perspective different from that of ITC.

The Department of Energy, Mines and Resources (EMR) is concerned in at least two ways. The department is responsible for administering the oil leases. Through the flexibility it has in interpreting the regulations concerning work commitments, it can have a great deal of influence on what sort of work is done and who does it. Also that department, through the Bedford Institute of Oceanography and the Geological Survey of Canada, has already contributed a great deal and has acquired considerable expertise. Indeed, the industry itself[2] credits these two agencies with the pioneering work that has "initiated offshore exploration effort". This department has further responsibilities for surveys and for obtaining environmental data in the area, and a requirement to dovetail its work with that of the industry. It also has a duty to make sure that maximum advantage is taken of the survey and exploration work carried out by the industry.

There are already regulations concerning the filing of cores taken during exploratory drilling. The information gained

[1]**Amoco brief to the Water Transport Committee,** ***loc. cit.***

[2]**Oilweek, p. 49. May 12, 1969.**

ceases to be proprietary after a suitable time interval. Similar regulations should be enforced concerning geological bottom samples taken by dredging operations, by divers or by submersibles. The department must remain fully aware of all kinds of data being obtained by the industry so that these data, together with those gained by government surveys and from reworking samples obtained by the industry, can eventually be used for the geological and geophysical mapping which is EMR's responsibility.

In addition to these federal agencies, each of the provinces concerned has duties and rights and needs to be consulted. Not only will they have views concerning the nature of the industrial development, but they will have to speak for the recreational industry and for the concern of coastal communities over pollution problems.

The large number of departments involved makes the problem of management of government interests in this offshore activity one of considerable concern. Many situations will have to be handled with great subtlety and flexibility.

We have seen a number of cases where lack of co-ordination among various arms of the federal government has produced results, which were not only frustrating and expensive to Canadian industry but were obviously inimical to Canadian national interests. No thread of policy is discernible which can be traced from one department to another. For example, an outside observer would not be able to decide whether it is policy to attempt to obtain appreciable Canadian participation in the *exploration* for offshore oil or, instead, to wait for the *exploitation* stage before trying to ensure a sizable Canadian involvement. If he ventures somewhat into the federal government labyrinth–as we have done–he finds that some agencies have policies all right, but not only are these policies uncoordinated, they often conflict!

A number of policy guidelines urgently need to be laid down–presumably by Cabinet. Some of these are: To what extent should the requirement to ensure a large Canadian participation in the offshore development be allowed to affect the rapid and efficient location and development of the resource? To what extent should the need for regional industrial development take precedence over the requirement for efficiency in Canadian participation, which might be greater if most of it occurred in the industrial heartland of the country? How stringent should be the regulations imposed in trying to reduce the dangers of pollution and other possible deleterious effects on the fishery or on recreational amenities?

It is our opinion that the ground rules under which oil companies operate in Canada should be changed only with adequate notice. One of the reasons that there is so much activity in Canadian waters is that Canadian regulations are relatively favourable and relatively stable. However, the nature of the offshore petroleum development activity is likely, for the next few years, to be a very volatile one. Any policy, no matter how stable, will have to be supported by a large number of *ad hoc* decisions. The various departmental responsibilities interact with one another, and the departmental authorities making decisions must not operate in ignorance of the effort and goals of other departments.

To ensure that the policy is carried out in a concerted fashion, we recommend that an Interdepartmental Continental Shelf Committee, consisting of senior (about assistant deputy minister level) representatives from the Departments of Energy, Mines and Resources; Industry, Trade and Commerce; Regional Economic Expansion; External Affairs; and Fisheries and Forestry be set up immediately. Its main function should be to review regularly the *ad hoc* decisions relating to continental shelf gas and oil developments which are made by various departments, to ensure consistency in approach. To this end, it should also operate as a kind of appeal board when an industry finds such decisions unreasonable or inconsistent. For general policy guidance this committee could be related to the Interdepartmental Committee on Resources. However, when policy clarification is required, requests for rulings will have to be carried by the representatives on the committee for their ministers. Representatives from appropriate departments of the provincial governments concerned should be invited to contribute ideas to this committee and perhaps take part in its deliberations.

In our opinion, a committee of the kind recommended above, meeting frequently, would be the most effective way of dealing in a concerted fashion with the rapidly changing situation. An alternative method might be to select a sort of "Czar" to control all the various aspects of problems that will arise. However, this arrangement might cause administrative difficulties, since it is not evident that there is any single department with a predominant interest, to which this individual could report. Thus we prefer the committee suggestion.

As we see it, the objectives which this committee should seek in administering regulations for the exploitation of petroleum resources can be categorized as:

1. Increase in the Canadian Gross National Product;
2. Increase in the opportunities for Canadians to be involved in rewarding, stimulating and challenging occupations;
3. Little or no adverse impact on the environment;
4. Regional economic development.

We do not wish to imply any priorities in listing them in this order. All are important and require prior policy guidance.

These objectives in themselves contain sources of conflict, and they do not wholly coincide with the objectives of the industry. The industry is international and has no special interest in increasing the *Canadian* Gross National Product; nor is it specially concerned that *Canadians* participate in the rewarding and challenging work. In the absence of suitable government action, much of the economic advantage, and most of the technological impact, will be in areas outside of Canada. It is our opinion that government intervention is required to ensure that sufficient Canadian advantage be gained from these activities in Canadian waters and from resources that may be found in Canadian areas.

It is most important to recognize that there are considerable advantages to be gained from the exploration itself–whether or not the expected resources ever materialize. The search for oil requires a high level of expertise in a large number of fields. A few examples illustrate. Oil drilling rigs need to be designed as well as built; so does the great variety of machinery and equipment that these rigs carry. Geophysical survey at sea requires specially fitted ships, very sophisticated equipment, and highly skilled personnel for both operation at sea and analysis ashore. Offshore activities require special forecasts of wind and wave conditions.

Canadians are fully capable of becoming competent in all of these activities. If a high level of proficiency can be acquired by working in Canadian waters, this expertise will be in demand in many other parts of the world. It can be the base of major export activity. For these reasons, it seems important to ensure significant Canadian participation and development of independent Canadian technology even during the exploration stages.

We believe that the possibilities for export form the key to the appropriate attitudes in formulating regulations and in encouraging Canadian participation in the industry. But if the export possibilities are to be achieved, Canadian skills will have to become fully competitive. Thus, Canadian industry should not be too closely protected. It will need some encouragement and perhaps some *initial* protection to permit it to overcome the inevitable "teething" troubles that will arise. However, in order that the Canadian industry should have a clear view of its international competition, some foreign participation should be permitted in all aspects of the work. Even within such a policy, foreign participation can be severely limited. We believe that expanded access to opportunities for work in Canadian offshore areas should be offered to foreign operators only on the basis of reciprocal arrangements permitting Canadian operations in foreign offshore areas. (Some care will have to be taken in adopting such a policy because of the possibility of foreign operators employing "flags of convenience". There is little advantage to Canadian operators in giving them rights to work, for example, off the shores of Liberia.) All regulations governing the operations of Canadian operators should apply equally to foreign operators working in Canadian offshore areas.

In this context, Canadian offshore areas include not only those areas over which Canada has full sovereignty (internal waters and the territorial sea), but also the much more extensive areas over which Canada has exclusive sovereign rights for the exploitation of bottom resources. Canada's sovereignty over its internal waters and territorial sea, and Canada's jurisdiction over fishing zones extending beyond the limits of the territorial sea, are asserted in the Territorial Sea and Fishing Zones Act (1964). This Act gives Canada exclusive control of access to the mineral and living resources in the water, on the bottom, and in the subsoil within the limits of Canada's internal waters and territorial sea, and to the living resources in the waters of Canada's exclusive fishing zones.

Beyond the territorial sea, Canada's sovereign rights over the natural resources of the continental shelf are supported by customary international law and the 1958 Geneva Convention on the Continental Shelf, to which Canada is a party. It states that coastal states have jurisdiction over the natural resources on the seabed and subsoil of the submarine areas adjacent to the coast, outside the area of the territorial sea "to a depth of 200 meters, or beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources". These rights are exclusive and *not* dependent on actual occupation, exploration and exploitation, and no other country can make a claim to the continental shelf, or even undertake scientific research concerning the continental shelf without the consent of the coastal state.

Lest our stipulation that regulations governing Canadian offshore areas should apply equally to Canadian and to foreign operators sound overly generous to foreign competition, we hasten to observe that some of the procedures that government departments follow have selectively *penalized* Canadian operators. For example, the Department of Transport required that the Canadian geophysical survey ship *Calgary Catalina* meet the standards of a cargo vessel. Her American competitors, registered in the United States, had the much less demanding classification of a fishing vessel. Our main concern is with the removal of these hidden penalties.

We believe that the regulations drawn up, and the enforcement procedures adopted, should encourage the development of Canadian expertise in the design of offshore exploration equipment of many kinds, and of permanent exploitation facilities. Each type of equipment–from drilling platforms to pipe fittings–should be examined to see whether or not there is a realistic possibility of developing a Canadian design and manufacturing capability which could become fully competitive in the international market in a few years. If such a capability exists, some portion of the Canadian market should be reserved for it. Perhaps some quota system similar to that employed in the textile industry could be adopted. Only if it is decided that there is no possibility of developing a Canadian capability that could become fully competitive in a reasonable time, should complete dependence on foreign supplies for *any* kind of equipment be permitted.

To summarize our philosophy: advantage should be taken of the probable existence of important resources of petroleum off the Canadian coast to develop a Canadian capability which would be competitive in the world market. Advantage should also be taken of a willingness to permit foreign operations in Canadian offshore areas in order to obtain reciprocal permission in foreign offshore areas.

Concerning this last point, we must emphasize that at present Canadians are operating at a substantial disadvantage. A major proportion of the world's offshore petroleum activity is in United States offshore areas. U.S. regulations are such as to make Canadian participation in this activity difficult or impossible. On the other hand, Canadian regulations are so much more generous that U.S. activity in Canadian areas is large, sometimes at the expense of Canadians. This problem arose in the course of a public information-gathering session which we held in Calgary. We were offered the opinion, expressed in an accent that could only have originated some 2 000 miles southeast, that "you can't fight narrow nationalism with narrow nationalism". Perhaps! But it is our opinion that *enlightened* nationalism is the appropriate Canadian stance in this context.

In addition to these important regulatory responsibilities, government has, through its laboratories, other responsibilities. While most of the geophysical work in this area can now be left to the industry, it remains the responsibility of these laboratories to prepare maps of the geological and geophysical structures of the whole area. They could demand from the industry immediate release of information on large-scale features, while leaving to the industry proprietary rights for those small-scale details that are of such importance in the location of hydrocarbons. Undoubtedly they will find areas in which they will have to carry out some surveys of their own in order to complete their maps. The presence of this industrial activity does not diminish–indeed, it increases–the requirement for government laboratories to gather and collate such environmental data as detailed bottom topography, the soil mechanics characteristics of superficial sediments, the probability of turbidity currents, and the nature of both mean and fluctuating current systems. In addition, government has a responsibility for knowing enough about the movement of surface waters to enable prompt and effective action to be taken in case of oil spills. Close collaboration is required between these government laboratories and the industry to ensure that the laboratories are not wasting their time by duplicating industry efforts or, on the other hand, are failing to obtain information which the industry has a right to expect of them.

A traditional government responsibility which will be accentuated by offshore exploration and exploitation work is the requirement to provide navigational aids. At present they are inadequate to the new demands. This situation should be looked into promptly in collaboration with the industry. One particular aspect of navigation presents a new, difficult and urgent problem. Oil leases granted by the federal and provincial governments are defined in terms of latitude and longitude. If an oil-bearing structure is located near a boundary between leases held by different companies, the exact position of the boundary becomes of very considerable importance. Unfortunately, our present ability to describe the exact location of a particular place at sea in terms of latitude and longitude remains inadequate. What is needed is some marine analogue of the "bench mark". The problem is not particularly easy. Buoys may be swept away by storms, or "salvaged" accidentally or intentionally. Bottom-mounted objects may be disturbed by groundfishing activity. What seems to be needed is some device *in*, rather than on, the bottom, which can be precisely located acoustically. It is urgently necessary that a suitable device be designed and constructed, and that sufficient numbers of them be laid in all areas in which oil exploration is active. Once laid, they should be located with maximum possible precision. It will probably be necessary to redefine the oil leases in terms of these best possible positions rather than the actual latitudes and longitudes, since it is unlikely that navigational techniques will become sufficiently precise in the immediate future.

Full exploitation of shelf resources will not occur until various jurisdictional questions are settled. At present there are several such questions. Within Canada there remain unresolved questions between the federal and provincial governments. In many cases the effects of these disagreements have been minimized because the oil companies have been able to reach parallel agreements with both federal and provincial authorities. However in others, particularly along the Quebec shores, the situation is more confused. Internationally, the offshore boundary with the United States has yet to be agreed upon, and there remains some indefiniteness about the boundary with Greenland. There is also a question to be resolved with France concerning how much of the shelf area falls to that country because of its possession of St. Pierre and Miquelon.

The oil industry has a great many possibilities to choose among when selecting areas for exploration. Thus, those areas in dispute will simply be neglected. If maximum advantage is to be taken of the resources, it is necessary that these jurisdictional disputes be resolved. It will probably be easier to resolve them *before*, rather than after, discoveries of actual fields are made, so that prompt action should be taken in dealing with these problems.

The Arctic

For the Arctic areas, the administrative responsibility is less divided than it is in more southerly latitudes, in that much of the responsibility lies within the Department of Indian Affairs and Northern Development. Nevertheless, in this case too, we recommend that a special Continental Shelf Committee be set up to undertake the responsibility of ensuring that there is consistency of approach in the administration of regulations.

There would be many advantages, in fact, if the *same* committee were used for all offshore areas–east coast, west coast, and Arctic, in which case the Department of Indian Affairs and Northern Development should be a member. Such an arrangement would give the industry a clear source for rulings and for information on policy, without having to run from one department to another every time they wish to step across the 60th parallel. The committee should be able to call on expertise, not only on petroleum and its legal aspects, but upon Arctic navigation, Arctic communication, Arctic ecology and ice problems. It also must be prepared to move quickly in the formulation of new regulations as the situation changes. It is impossible to foresee all eventualities.

As can be seen in Table II.1, potential oil reserves offshore in the Arctic appear to be about 20 per cent of the whole Canadian potential, and are comparable to those of the shelf off the Atlantic Provinces. The spectacular find at Prudhoe Bay in Alaska has attracted particular attention to this area. One needs little persuasion to believe that there are many very special problems associated with the Arctic. As with the east coast, we believe it to be in the national interest to ensure that advantage is taken of the urgent need to solve these problems. Wherever possible, the expertise developed should be Canadian expertise. Some already exists, and it is necessary to bring it to bear upon the problems that will be encountered.

Some of these problems are common to both the land and the sea environment. For example, the problems of being able to live and work on the surface when air temperatures sink below −40°F are rarely encountered in the southern portions of Canada, but are frequent over both land and water during the Arctic winter. E.L. Lewis, of EMR's Frozen Sea Research Group, who has worked under these conditions, finds that "few, if any, commercially available items will work reliably in an extremely cold environment. Major modifications or adaptations are usual; this problem extends from vehicles and motor generator sets to insulation on electronic wiring." Special equipment, some of it very sophisticated, has been developed in Canada to overcome these difficulties. However, it is only very recently that there has been any industrial interest in these difficult problems, and present capabilities mostly lie within government departments and, to a lesser extent, in the universities. Here again we see the picture that recurs frequently in these pages: a high level of special competence and specialized expertise which is not associated with any manufacturing capability.

The problem is acute in this particular case. In the course of our study we found that, as a rule, the industry was unaware of the existence of this expertise. It should be a function of the peripatetic information service, which will be proposed in Chapter VI, to overcome such information lacunae.

Canadians should be among the world leaders in cold weather technology. At present our competence in these fields is less than is often assumed by those in other countries.[1] We should take every advantage of the Arctic activity which oil exploration and exploitation promotes to ensure that we achieve this position of leadership. Vigorous efforts should be exerted to bring those experts in the universities and the government service who have gained competence in dealing with Arctic conditions into collaboration with those industrial users who need the information. Within the next two or three years, the urgency of this kind of collaboration may be so great that even some curtailment of the government's own programs should be acceptable if the demand by industry for consulting services is so heavy that it makes serious inroads on the time of government experts.

[1] Brief on sea ice research related to marine sciences and technology in Canada, prepared by the Working Group on Ice in Navigable Waters. Canadian Committee on Oceanography. November 1969.

The probability that oil will be found in sediments of the Canadian Arctic shelf seems very high indeed. There are, however, serious difficulties both in exploration and in exploitation. These difficulties will be overcome in one way or another, but we must face the fact that there is a high probability of the following sequence of events.

At present, real competence in dealing with the Arctic situations that will be encountered by the oil companies hardly exists anywhere. However, there are well-organized consulting firms in the United States with a marginal level of competence. When the international industry requires solution to a problem, it is most likely to seek the aid of these consultants. Since they are not really familiar with Arctic conditions, they will make many mistakes in their first efforts. However, they will learn from these mistakes. When the next question arises, they will be able to supply answers based upon real experience.

In our opinion, it is in Canada's interest that this sequence of limited capability leading to experience and thus to real expertise be gained by Canadians. Unfortunately, the initial starting position of Canadians is somewhat inferior, not so much in knowledge as in organization. Some government influence is required to bring about a favourable result. We believe that this influence will be most effectively applied by providing government support for a few projects with clear objectives. Two such projects are discussed below.

1. Geophysical Study of the Arctic Shelf

There are serious problems in attempting geophysical exploration of sediments underlying ice-covered water. Standard procedures for producing seismic reflection profiles at sea ordinarily yield very high-quality results; these to some extent offset the difficulties of working at sea relative to working on land. However, in ice-covered waters, back-scattering from the under surface of the ice and other acoustic phenomena associated with this ice cover can seriously impair the quality of seismic data obtained. Further, the difficulties of moving over or through the ice very sharply reduce the rate at which data may be obtained. It is our expectation that these problems will ultimately be solved. It is in Canada's interest that the requisite expertise be obtained by Canadians. To this end, we propose a systematic, at least partly government-financed, geophysical survey of an area of the Arctic shelf.

It is preferable that as much as possible of this work be contracted out to Canadian enterprises and that little or none be done in-house by government laboratories. More specifically, we suggest that a systems engineering team should be established to devise an appropriate system. (Government should provide the systems manager but perhaps not the systems engineers.) Activity both on and below the water surface is envisaged. Individual components of the system would be contracted out to Canadian companies. The object would be not only to get the work done, but to engender development and dissemination of the wide variety of expertise required for working on Arctic ice and in Arctic water. The expectation is that when Canadian companies have this expertise, it will be called upon by other organizations in this and other countries, notably the oil companies, for their own needs. The government-financed activity would then become a relatively small but steady input to provide "bread and butter" continuity.

At least initially, there may be advantage if the government-financed survey is concentrated in the waters of the Northwest Passage between the Arctic islands. This would help to reinforce the Canadian presence in these waters. Except for such things as navigational aids and icebreaker support, the government input into this activity should be merely overall direction and funding. Government scientists and technologists with knowledge relevant to this work should be freely used as consultants, but the principal objective is to increase the competence of the industry.

Ice presents problems not only for exploration, but also for the exploitation of resources on the shelf. Again, we believe that these problems should be accepted as a challenge, and that expertise should be engendered which will not only lead to the solution of these problems, but also become a national asset which can be called upon to solve other problems both here and abroad.

2. Drilling from the Bottom

There are a number of possible ways of undertaking exploitation of oil in the offshore Arctic sediments. It is our belief, however, that it is in Canada's interest to develop a capability for fully submerged drilling. The reason for this belief is that while, conceivably, other techniques might be preferable for working in ice-covered waters, more than for any other technique technology developed for drilling from the bottom would be applicable elsewhere and to other problems. The skills engendered would have wider than strictly Arctic applications.

Again the procedure would be to set up a systems engineering group to produce an overall design, and components would be contracted into Canadian enterprises.

There should be no requirement that the initial developmental studies and drilling be in Arctic water, although for Canada, the ultimate aim includes such activity. Care should be taken to ensure that surface support could work under rigorous Arctic conditions.

Work of this type will require some sort of submerged living space. Whether or not this should be at atmospheric, ambient or some intermediate pressure requires close study. All possibilities have both advantages and disadvantages. We do not contend that Canada *must* participate in the ambient pressure "sea lab" work which is taking place in various other parts of the world, but we do not reject the possibility that this may be the optimum way of dealing with certain problems. It is almost certain that underwater drilling activities will require some mix of the use of free-swimming divers, submersibles with manipulation capability, and submersibles with diver lock-outs.

The choice of technique will greatly influence the design of a specific technological system, including the type of surface support required. Divers can now work in more than 600 feet of water, and saturation diving techniques with diver lock-outs from submersibles and ambient pressure underwater habitats have been demonstrated. Men can do useful though limited work at great depth. The industry feels that the use of divers in deep offshore oil operations will be marginal until underwater work systems are developed to augment the divers' capabilities. Manned submersibles can now perform sophisticated operations at great depths, with the added advantage that personnel, working at normal surface pressure, are not submitted to a lengthy decompression cycle at the end of each dive.

Several atmospheric pressure, uncapsuled, well-head completion systems have been designed, and their potential is now being assessed. The advantages of having a man working at normal surface pressures are well recognized, but the problems of personnel transfer through an air-lock, of corrosion, of marine fouling and those problems associated with the pressure differential between the marine environment and the "shirt-sleeve" environment of the capsule (e.g. stresses, leaks) will require an intensive R & D effort to make this concept a reality. So will problems arising from even small hydrocarbon leaks into the encapsuled volumes.

In order to design offshore drilling rigs and underwater installations (e.g. habitats, pipelines, storage tanks), there is a need for environmental data such as wind, wave, sea-ice, current and icing conditions. Unfortunately, at the present time, there is but sketchy information on environmental conditions, and installations have been designed in semi-ignorance. Aside from adding to the high cost of offshore operations, this lack of knowledge increases the risk of catastrophe, endangering both human lives and the environment. The industry feels that government can make a significant contribution in the development of Canadian marine resources by providing this badly needed environmental information. There is a special requirement for studies on Arctic conditions in order to provide guidelines for industrial operations. We must ensure that Canadians become among the world's leading experts at all of these activities in conditions of very cold water. Since very cold water occurs everywhere in the ocean at sufficient depth–often not particularly deep–this expertise will be in demand throughout the world.

These projects will cost money. Where is it to come from? The simplest answer is that it could be regarded as a direct government investment, as the following conservative calculation shows.

Assume that the Arctic offshore yield is one billion (10^9) barrels per year. (The industry will be very disappointed if it proves to be so small.) At present prices, this is worth more than $2 billion.

Except for profits to the companies and payments to governments in return for exploration and exploitation rights, this money is spent by the industry on the goods and services needed for exploration and exploitation. Many of the goods will be custom engineering products of a high technological content. Many of the services will be provided by consultants who are well educated and well informed. It is our contention that it is this kind of goods, and this kind of services, which is likely to be provided from outside the country unless there is government action to ensure that Canadians are in a position to provide them.

Assume that government action results in an increase in the Canadian participation in the provision of these goods and services which amounts to only 5 per cent of the value of the resulting production. (We should be desperately disappointed if it is so small.) This amounts to $100 million a year of industrial activity in Canada which would otherwise take place outside the country.

Using a conservative economic multiplier of only 2.5, we then expect an increase in GNP of $250 million a year.

In recent years, federal taxes have yielded about 17 per cent of GNP.[1] The increased tax yield is then about $40 million a year.

Assume that the yield does not begin until ten years hence, and that interest rates are as high as 8 per cent. The present worth of $40 million a year starting in ten years at 8 per cent is $230 million.

Even a banker should be willing to place $150 million now in an investment with a present worth of $230 million. In Chapter VI we propose an Ocean Development Corporation as a vehicle by which the federal government may make such investments.

Note that these considerations are independent of the approximately equal sum in taxes which will accrue to the provincial and municipal governments, of any expertise that can be sold elsewhere, and of the general satisfaction of increasing both the standard of living and the sense of self-dependence of Canadians.

(An economist will recognize that this account is oversimplified. If in ten years time, in the absence of such Canadian investment, there were no unemployment or underemployment, then the force of the argument for such an investment would be weakened. But this seems unrealistic, and we point out that the kind of activities envisaged call for highly skilled, well-paid personnel.)

As is the case in the eastern offshore region, there are aspects of government's traditional responsibility which must be accepted in these northern waters. Here, too, there are navigation problems. In many regions of the Arctic, these may be rather easier than in the eastern offshore, since the island complex provides bases for installations for which there can be no analogue on the Grand Banks.

[1]Dominion Bureau of Statistics.

Navigational aids are required, both for the greatly increased traffic which the oil exploration is producing, and to provide boundaries for oil leases.

Again as in the Atlantic area, there is a requirement to obtain better information on bottom topography, the nature of superficial sediments, and water movements. There is also a very serious requirement to obtain good information on ice movements. For example, if exploratory drilling is to be attempted from structures resting on the ice, there is a very great difference between *really* fast ice and *nearly* fast ice. Drift of a few hundred yards over the course of a month or so would be very serious.

Communications present especially serious problems in the Arctic. In those areas near the north magnetic pole, there are always special difficulties with radio communication. The Armed Forces have expended a considerable amount of effort in attempting to overcome these difficulties. Much of the expertise is now in a civil department–the Communications Research Centre (ex-DRTE) of the Department of Communications. It is important that this expertise be made as available as possible to private industry and other civilian groups now working at high latitudes. The problems may be more in the "software" of organization and operational methods than in hardware, but to learn how to handle software also calls for expertise and training. We have encountered considerable concern among industry representatives over communication. Very serious attention must be paid to this problem, because under these rigorous conditions not only are there difficulties with most kinds of communications, but frequently good communications will literally mean the difference between life and death.

There are certain other special problems in the Arctic. The greatly increased Arctic activity, including the arrival of many individuals with no previous Arctic experience, means that there must be greater capabilities in search and rescue. If, as seems likely, there is to be civilian work using submersibles under the ice, additional special problems of search and rescue arise. Some government agency will have to take responsibility for designing safety regulations and issuing licences for various kinds of vehicles. Just because some foolhardy group of individuals is willing to take great risks seems to be no reason why the Canadian taxpayer should be saddled with heavy expense arising from the humanitarian imperative of rescuing them from the consequences of their folly.

One can now find operating in the Arctic private concerns with financial resources far greater than in the past. These companies are not in the least horrified by the $5000-a-day operating costs of a large icebreaker. If they need one and are willing to pay for it, they see no reason why they should not have one.

Neither do we! It is our opinion that while the federal government continues to have a Canadian monopoly on large icebreakers, they should be prepared to rent out services. The priority of such services should not be placed below that of government operations. *All* the demands for icebreaker time should be scrutinized, and priorities set so as to optimize service to the national interest.

This must be only an interim measure. We would be in a more favourable position if there were a few privately operated large icebreakers, which could be far more flexible in serving private needs than can government ships. This end could be met in the way suggested for research ships in Chapter VI.

In recent months public attention has rightly been drawn to the dangers of pollution in the Arctic. Special procedures will have to be worked out to deal with oil spills in this region. (We reject the notion that it is possible to prevent such spills. Only by evacuating the area altogether would that be possible.) At these low temperatures, and with the limited number of biological species present, the biodegradation of oil will probably be much slower than at southern latitudes. Further, ice-congested waters tend to be calm.[1] Thus there is little tendency for the oil to become emulsified by wave breaking, and it is thus less subject to the action of organisms. On the other hand, this very calmness of the water makes the possibility of recovering oil from the surface more feasible, and it is likely that treatment of oil spills should stress this aspect. In the summer of 1969, two barges carrying drums of petroleum products sank off Melville Island. The drums will corrode and the oil will then escape and rise to the surface (if it has not already done so). Some effort should be made to take advantage of this unfortunate event in order to learn what becomes of oil spilled into the Arctic seas.

Other government activities in the Artic offshore should closely parallel those recommended for the east coast waters. Most of the geophysical exploration should be left to the oil companies. Again there is a government responsibility to produce maps. Just as the Government's efforts in the Polar Continental Shelf Project, which explored a large area of shelf off the Arctic archipelago, made a considerable contribution to the recognition of a resource potential in that area before the industry showed any interest, so further government activity is indicated in those regions outside and beyond where the industry is prepared now to operate.

If oil is to be moved in the Arctic with large tankers, then there will be special problems concerning navigation in ice. However, these will not differ in kind from the problems that will arise from other large ship operations such as those of ore carriers. These problems will be discussed in Chapter IV.

The question of sovereignty in the Arctic has attracted considerable attention recently. As was pointed out in the previous section, the 1958 Geneva Convention leaves no doubt about Canadian sovereignty over resources in the bottom sediments and, indeed, over exploration aimed at discovering such resources. In this context, the only immediate problem

[1]Ice in Navigable Waters brief, *op. cit.*

is that of the offshore boundary between Canada and Alaska. Since the Prudhoe Bay discovery is very close to this boundary, the question has become rather acute and there is some urgency in reaching an agreement.

It is not our intention to enter the debate on how Canada should assert her claims to sovereignty over the waters in the passages within the Arctic archipelago. We do point out, however, that ice-covered waters are significantly different from other passages. "Innocent passage" is not nearly so passive a concept when it involves breaking ice. If the passage is to be kept clear by Canadian icebreakers it acquires some of the character of a canal, requiring regulation and supervision by the coastal state. Even if the passing ships break the ice themselves, the result is not purely passive. In cutting their way through the ice they impede others who may wish to move *over* the ice. Ships passing through ice-covered water in cold weather greatly increase the water vapour content of the air in the vicinity. Not only do they produce water vapour by burning fuel, but they create open water from which evaporation may increase as much as one hundredfold. Fairly dense fogs may form which will have an impact on all kinds of transportation. Oil pollution of the waters resulting either from accidental spills or from deliberate bilge pumping, could have ecological effects which would make the passage far from innocent. These new dimensions to the concept of "innocent passage" require the development of new national and international laws concerning them.

The West Coast

The west coast is a very special case. As can be seen in Table II.1, the potential reserves in this area are relatively small, although it should be noted that when compared with American Gulf Coast figures, even here the possibilities are far from negligible. Shell Oil considered it worthwhile to have the large Sedco 135-F rig constructed in Victoria for exploratory drilling, and a sizable drilling program has been completed. (The rig has now left Canadian waters–it amounts to an export–and there is no present activity; however, there remains a good deal of territory under lease and more work is expected.) Even the comparatively small oil potential off the west coast can, if realized, make a substantial impact upon the British Columbia economy.

However, British Columbia is a wealthy province with a large variety of other resources, and it may be the public will to forego some of these economic benefits for the sake of the less tangible asset of the environment. Concern over the possibilities of pollution, following the ill-famed Santa Barbara oil spill, is now attracting active discussion among the press and public of the west coast. Oil exploration is projected in the Strait of Georgia, an area which is highly valued by the local population for its scenic and recreational value as well as for its sport and commercial fishery. Considering the enclosed nature of these waters, it is essential that extraordinary precautions be taken to prevent even a relatively small oil spill. It is our opinion that the provincial government, which claims jurisdiction for oil exploration in the area, and the federal government, which has jurisdiction over the fishery, should jointly instigate a thorough study of the potential impact of both oil exploration work and the consequences of a possible discovery. The study should be undertaken with dispatch, and the result made public, so that informed public debate can ensue and the pros and cons of carrying on with oil exploration decided in the political arena.

This study could be the first part of a deeper and more generalized study of the Strait of Georgia, which is proposed in Chapter V. If the decision is to deny permission for oil exploitation in the Strait of Georgia area, fairness demands that the oil companies be compensated for the expenditures on exploration in this area. Fortunately, these expenditures are still small within the Strait.

Offshore, the balance of factors tilts toward pursuing oil exploration and exploitation. The results of the Shell drilling program are not yet in the public domain, so whether or not further work is likely is not known. As will be discussed in later chapters, this whole region is of immense geophysical interest from a basic science viewpoint, and there are possibilities of resources other than oil. It is thus to be expected that university and government geophysical work will develop here with some intensity. Government responsibility to produce large-scale geological and geophysical mapping is at least as great here as elsewhere.

There are boundary questions concerning the west coast as well as other areas. Neither the northern nor the southern offshore boundary has yet been agreed upon with the United States. Despite the Supreme Court opinion of 1968, which supported the federal government claim to all mineral rights within submerged lands, the internal jurisdiction situation remains confused. No action has yet been taken on the Prime Minister's proposal of December 2, 1968, in which the federal government established "mineral resource administration lines", within which it offered to leave both administration and revenues to the provinces, but outside of which the administration would be federal and the revenues equally divided between federal and provincial governments. Until agreement is reached, it has become clear that the federal government does not consider that it has given up jurisdiction on the territory inside its proposed resource administration lines. The resulting confusion must be inhibiting action on the part of the industry. This is particularly true for the Strait of Georgia, an area inside the resource administration lines. If there is a delay in industrial activity there because of this indecision, such delay is perhaps more advantageous than disadvantageous. It may provide time for the study suggested above on the desirability of oil exploration and exploitation in the Strait of Georgia, before the industry commitment becomes too large.

For all shelf areas, the seaward boundary remains indefinite. The 1958 Geneva Convention of the Continental Shelf does not admit of the drawing of sharp seaward boundary lines. A geophysical definition is desirable. The question will be returned to in Chapter IV.

Chapter III

Marine Science and Technology in Canada

The term marine science is used here to embrace all scientific activity related to studies of the sea. Because it deals with a large and complex system, marine science shares with other environmental sciences a heavy dependence on data collection directed to description of the system. Data collection and analysis must therefore be considered as much a part of the science as are those activities usually classed as "research". In the same way, marine science is heavily dependent on special instrumentation and engineering. These activities are sometimes classed as technological rather than scientific, but are necessary to the continuing requirement for more precise description. Sharp distinctions between scientific and technological activity are neither possible nor desirable.

In this chapter it is not our intention to attempt a comprehensive review of marine science or to prepare a condensed textbook. It is important, however, to outline some of the problems which concern the scientists, to indicate something of their interrelations, and especially to attempt to put the present role and opportunities of the scientific effort in Canada in perspective.

The object of any science is to achieve a level of understanding which allows accurate prediction.

In this, marine science shares certain characteristics with the atmospheric and earth sciences. In the first place, these branches of environmental science are strongly interdependent. Winds are the predominant generating force for ocean currents, but the energy in the atmosphere is largely derived from the sea. Sea and atmospheric conditions together set limits within which biological communities live, but these in turn influence the chemistry of their medium and the absorption and deposition of energy in it. Living organisms have profound influence on the nature and thickness of sediments which now cover much of the exposed land surface and which erosion gradually delivers to the sea floor. Ultimately, none of the components of this vast interacting system can be studied in isolation from the others.

A second characteristic of the science of such a system is that observations of changes and differences, on which all science depends, are rarely open to deliberate manipulation by the scientist. Experiments in the environmental sciences take the form of long-term observations at particular stations, or comparative observations at selected stations. Because any observation point is liable to the simultaneous influence of many forces, the observations required are complex and tests of hypotheses about the nature of certain phenomena often require special times and places of observation.

In the face of the complexity of natural systems, it is a third characteristic of the science that modelling of simplified systems plays an important role. These models may take the form of large analogue models, which are scaled-down versions of particular regions such as harbours and inlets in the study of tidal or ice action, or they may be electrical analogues, or complex digital computer or analytical models describing in mathematical form the theoretical relations among the parameters studied. Predicted effects may then lead to a knowledge of critical observations which could be used to test the hypotheses on which the model was built and lead to the formulation of more accurate models.

The combination of observation, description, model-building and testing has led to considerable knowledge of the sea and our ability to account for both events in it and its effects on our land environment. This new knowledge has been in part responsible for the recent sharp increase in our interest in it, as outlined in earlier chapters. But this knowledge is rudimentary compared with even the present state of our demands for information. Our ability to *predict* is still limited in the extreme. Even in simple description we have far to go. It has been estimated, for example, that the accuracy and degree of detail of present maps of the ocean floor are comparable to maps of the land surface of the earth published 250 years ago.

It is a fourth characteristic of the environmental sciences that public support for the scientific work has been especially closely linked with the appreciation by society of a practical need for the results. Thus, for example, hydrographic charting of coasts and harbours, basic to any description of the system, has been undertaken primarily in the interests of shipping. A study of the oceanic currents was pursued when it was realized that this could result in substantial savings in transportation costs. The requirements for successful fishing supported earlier work in definition of migration routes and attempts to estimate the abundance of fish. The requirements of bathymetry for cable laying and fisheries together gave rise to extensive charting of the continental shelves and to spotty observations in the deep sea. Development of underwater acoustics, perhaps the most powerful tool for observation in water, took place primarily during the two world wars when its application to anti-submarine warfare was recognized. Now the development of the offshore oil industry is certain to lead to greater demands than ever for oceanographic information.

This dependence of support for marine science on possible applications is perhaps understandable in view of the expense of the undertaking, requiring substantial ships and elaborate instrumentation for even a beginning. But it is perhaps a measure of the cost of this limited approach that we have been so slow to appreciate the importance of the influence of sea conditions on our terrestrial existence. It is only in the past decade that we have begun to understand that changes in the temperature of the ocean off Peru can give rise to atmospheric effects which influence the weather in northern Europe, or that the outflow of rivers of the U.S.S.R. into the Arctic Ocean can affect the climate of the Maritime Provinces. It is even more recently that we have come to appreciate the extent to which man's activities can change this system unintentionally, or that with sufficient knowledge it is within our power to alter it intentionally. In this truly changing world, events in the sea play a major role as mediator and modifier, which may in some cases diminish or in others magnify the effects of events we set in motion. This realization has led to a demand for a new depth and detail in our knowledge of the sea. In Canada we may have been wiser than we knew to have developed the environmental sciences, including marine science, to the extent we have in the past. Our strong background presents us with both special opportunities and special responsibilities in building the new knowledge required of this most important part of our environment.

The Scientific Problems

Phenomena in the Middle Scale of Observation

It has become almost a truism to point out that studies in marine science comprehend observations of phenomena which vary in size from millimetres to thousands of kilometres, and in time from milliseconds to thousands of years. In fact, our initial observations begin in the middle of our possible range of scales, and a majority of the problems actively studied are still related to phenomena which are relatively readily observed.

The *tides* are the sea phenomenon which by their size and regularity most impress the casual observer. Observations of daily change in level at specified points early led to recognition of their relation to motions of earth and moon relative to the sun. However, observations at one place are not so readily related to those at another. These contrasts, together with the more complex tidal flows, have required considerable theoretical elaboration for understanding. The phenomenon is now well enough understood to permit predictions of tide levels in well-observed areas close to shore, useful for many purposes of near-shore navigation. We still know relatively little about tidal currents.

However, because tides are such an important component of observed variability in the sea, it is necessary to take them into account in interpreting almost all other observations. Tides also provide an important source of energy for mixing processes. There is thus a continuing requirement for accurate prediction, which implies a need for better observations, particularly of offshore tide levels and of currents in all areas. These are of special concern in offshore areas where exploratory drilling for oil requires a knowledge of tide heights and of current velocities at all depths. Until recently Canada was a "colony" in tidal analysis, depending for calculations on the Tidal Institute at Liverpool, England. However, since 1964 this task has been taken over completely by the tidal analysis group in the Department of Energy, Mines and Resources at Ottawa. *Since the better the theory, the fewer the observations needed,* this unit is working on improved tidal computation models to supply better backing for oceanographic studies, as well as improved coverage of the prediction service for localities of interest to Canadian science and industry.

The nature of *ocean currents* is less readily observed, and the first general recognition of their magnitude and persistence as "rivers in the sea" was brought to light only in the mid-nineteenth century by a U.S. naval officer, Maury, on the basis of a study of ships' logs. The recognition of savings in ocean transport costs led to strong support for the studies, especially during wartime when their importance to convoys as well as to submarine warfare was so obvious. Canadian work in this field was confined largely to the continental shelf until recent years when the Pacific Oceanographic Group under the direction of Dr. J.P. Tully played an important role in working out the circulation of the North Pacific, and gained an appreciation of the magnitude of variations in water mass structure in relation to the needs of fisheries and defence. More recently, with the establishment of the Bedford Institute, we have begun to appreciate the real complexity of the Gulf Stream and the multifold influence of its branches, mixing with components of the Labrador current and with deeper waters to form the water which dominates the North Atlantic circulation. Throughout the world it is now recognized that, in the border zones at the edges of the continental shelves, short-term variations in temperature and currents–of the order of a few days and related to the major current variations–can be greater than any expected average seasonal trends, and have a profound influence on the state of water, ice and biological productivity on the shelf. Predictions of such variations on both coasts of Canada require a far better understanding than we now have of time-dependent events on all scales.

Underlying all the problems outlined above is a concern with what is happening in the *ocean waters*–what mariners call "the high seas". Almost all time-dependent variations in water temperatures and currents on the banks, in the rates of travel of icebergs, in the "upwelling" of waters along the Pacific coast, or meandering of the Gulf Stream adjacent to the Scotian shelf and Grand Banks, the very mechanisms of refertilization and dilutions of the continental shelf waters, seem to depend on surges or large wave motions originating in the great oceans. We know almost nothing about these motions except that they occur. Furthermore, the organisms living in more or less distinguishable "layers" in the waters above the oceanic depths, which perform extensive vertical diurnal migrations, probably collectively form the largest mass and turnover of animal protein on the earth. Where these layers come in contact with the bottom at the continental slopes, they will probably be economically exploitable with minor modifications of present fishing techniques and are likely to form an important component of future world protein food supplies. For combinations of such scientific and practical reasons, there is a growing need for information on the deep sea. Considering the extent of our coastal shelves, marine science and the marine industry in Canada have especially strong reasons to be interested in the deep-sea problems in the North Atlantic and Pacific. Ways of carrying out such work must be found in the programs of our major marine science centres.

It is increasingly clear that differences in size and configuration in these two northern oceans, together with the strong east-west asymmetry of ocean current mechanisms, lead to rather striking differences in expression of the major generating mechanisms in terms of the chemical and biological nature of the systems as we see them on Canada's coasts. Understanding the ways in which these ocean systems work must eventually involve more detailed comparative studies of them. Some progress in this respect may emerge from the present "Round the Americas" cruise of the Canadian research vessel C.S.S. *Hudson.*

Of key importance in understanding and predicting coastal water conditions, and events stemming from them, is a knowledge of the *mixing mechanisms.* The mixed waters of the shelves are complex and the biological productivity per unit volume in them is generally high. This results partly from the large admixtures of mineral-rich deep ocean water with fresh water outflows in the large estuarine mechanisms of, for example, the St. Lawrence and Fraser Rivers. However, the energy for this mixing comes from a variety of sources, including flow from the rivers, tidal action, local wind circulation, internal waves and eddy patterns generated at interfaces between currents. These components are measurable with modern instrumentation. Such observations are required before it is possible to test the more elaborate theoretical models on which improved predictions could be based. The present low level of physical oceanographic effort in Canada can yield such understanding only slowly. The results are, however, basic to the chemical and biological knowledge needed to solve the problem of pollution and fisheries, as well as to the prediction of movement of surface waters and modifications in them on which information is needed if we are to develop extended range weather forecasting.

Changes in large estuarine-type mixing processes have a special significance in Canadian waters but are as yet very little appreciated, since major short-term alterations are rare anywhere. In those places where engineering works *have* radically altered estuaries–for example by changing the runoff pattern–we have generally not been able to study the effects of such alterations because we did not have good data on the area taken before the change occurred. These changes can be large. One of the most dramatic of them accompanied the recent building of the Aswan High Dam in Egypt, which retains a major fraction of the water once flowing into the Mediterranean. After its completion, fisheries pursued for centuries off the mouth of the Nile disappeared and the surface waters of the eastern Mediterranean have markedly increased in salinity. Further effects on productivity can be anticipated. Little-understood natural forces, which from time to time produce changes of temperature in the surface waters off Peru, give rise to marked changes in fisheries and in the bird life, hence the rate of guano deposition on the islands. In this case, oceanographic and meteorological studies have suggested that these oceanic fluctuations set in train climatic effects which have measurable and possibly predictable effects on the climate as far away as northern Europe.

In Canada, changes in major currents and mixing processes are less striking than in the Nile and Peru examples but may still be of major importance. For example, regular haddock migrations took place in the Gulf of St. Lawrence until the mid-1930s. Since then they have declined, and haddock are now almost unknown there. The cause of the change is not known. It may be partly related to fishing effects because most of the migrants were large fish, and with heavy fishing large sizes are fewer than they used to be. But the effect almost certainly reflects change in the physical nature of the system as well. During the past 50 years, the fresh waters of the St. Lawrence drainage basin have been gradually regulated for power development, and up to 1960 the developments are estimated to have reduced spring and early summer runoff by 20 to 30 per cent, with a corresponding increase in fall and early winter.[1] The expected result is a decrease in spring and summer mixing and an increase later on, leading to an elevation of both summer and winter surface temperature. This effect would have been enhanced with construction of the St. Lawrence Seaway. Unfortunately, water temperature records are too infrequent to permit direct testing of the hypothesis, but May to October average air temperatures at Pointe-au-Père show a rise of 3 to 4°C (5 to 7°F) from the beginning of the century to the period 1959-64. Such important local climatic effects, if due to changes in river flow, would have a major influence on winter ice cover in the Gulf. Since further river works are planned in this region for the next ten years, there appear to be strong reasons to study this system in some detail.

A discussion of the importance of understanding mixing mechanisms in Canadian marine waters would be incomplete without further reference to their relation to *ice formation*. Except for the British Columbia coast, ice dominates the whole Canadian scene in winter, and in the north is to be reckoned with at all seasons. This central fact has been dramatized during the past year by the voyage of *Manhattan*, but is part of the lore of every Canadian schoolchild who has been introduced to the history of early Canadian exploration and the persistent attempts of Europeans to find the fabled Northwest Passage. The pattern of freezing and thawing of the northern waters, including Hudson Bay, determines the seasonal temperature cycles and rainfall patterns of much of the country. The geological evidence of warm Arctic conditions in the late Mesozoic, the warm Cretaceous seas which covered much of the continental interior, and the Pleistocene Glacial periods, all attest that the present is by no means a stable state.

While long-term climatic changes are of special interest to Canadians and are further dealt with below, year-to-year variations are well known to everyone. The sea plays an important part in the short-term climatic variations. Deviations of ocean surface temperature from the climatic mean have, by hindsight, been shown to be the probable cause of systematic differences in the hemispheric wind field–which may, in turn, induce new deviation in ocean surface temperatures. There is real hope that we may soon understand such situations well enough to make useful predictions. These will constitute forecasts of short-term climatological variations. When they become reasonably accurate, they will have very widespread usefulness in the agricultural, forestry and construction industries–to name but three. However, civilization is already causing changes in conditions and it is essential as a minimum to be able to anticipate their effects.

In the case of the Gulf of St. Lawrence, sea-ice formation and melting are apparently responsive to the mixing of warmer, deeper oceanic water with cooled surface water. The general vigour of this mixing process depends on both rainfall, which determines land runoff, and wind-generated currents, which in some cases may be initiated far from their site of action. In the high Arctic, the surface waters are of relatively low salinity, largely owing to the influence of the rivers draining north from Russia, with a minor contribution (perhaps 10 per cent) from the Mackenzie River. This situation may soon be changed by major U.S.S.R. water diversions south into the Caspian Sea area. While this may reduce the thickness of the surface water of low

[1]Neu, H., personal communication.

salinity, the ultimate effect on ice formation is probably dominated by the balance between surface cooling and the contribution to the heat budget of the deeper warm water entrained by the river discharges. The relative magnitude of these, and other heat budget components in the high Arctic, is not accurately known.

An area of equal importance to the climate of central and eastern Canada is Hudson Bay, where it appears that the heat budget is dominated by the very high albedo due to total ice and snow cover from January until well into early summer. But the temperature of the outflowing water is also strongly influenced by the outflow of the major rivers from the prairies, which entrain of the order of 10 times their volume of deeper salt water. Strong river discharge is likely to result in higher surface temperatures, especially in autumn and early winter. When this mixed water flows out through Hudson Strait, it forms a major component of the Labrador current. The temperature of this flow influences the melting rate of icebergs derived from the northern glaciers and is a major influence on the east coast climate. The climatic consequences of a reduction in the river discharge into Hudson Bay, such as would follow from any of the major water diversions that have been proposed in recent years, need to be appreciated. Major alterations in the seasonal outflow are now in progress in the interests of irrigation and hydroelectric power development, and could produce important changes in the time of major outflow, parallel to those discussed for the Gulf of St. Lawrence. It is clear that the mechanisms of ice formation, the influence of its characteristics on rates of freezing and thawing, and especially the influence of oceanographic processes involving ice on both the land and water climates, are important subjects for marine science study. These are areas in which relatively little work has yet been done in Canada.

Smaller scale patterns of surface water-mass distribution have been known for many years by fishermen and those familiar with the sea, through the presence of exotic fishes associated with bits of flotsam and jetsam. It is only in recent years that it has come to be recognized that water swirls and gyres can arise from a variety of causes and may maintain their integrity over periods of days and weeks–long enough for their biological, chemical and physical characteristics to be appreciably changed. It seems highly probable that the pattern of these occurrences has profound effects on the nature of biological processes, as well as important implications for design of oceanographic sampling programs. Their nature and importance in deeper water are virtually unknown. Studies of this order of complexity call for shipboard computations in association with field programs, a practice that has been slow to develop in Canadian coastal oceanographic studies.

Water current patterns, water climate and mixing processes together have profound influence on *biological productivity.* It is against this pattern of change that fishing creates additional effects. At the present time, the east coast of North America, from Greenland to Cape Cod, is one of the most heavily fished regions of the world. Major effects of this fishing on the age-composition and relative abundance of selected species of fish have been documented by Canadian scientists in association with scientists from the United States and some 14 European countries which make large catches there. If the larger sizes of certain species can be legitimately regarded as a biological system independent of the rest of the ecosystem, it can be shown that for a number of them, such as haddock of George's Bank, the total yield of those larger fish cannot be substantially increased by increased fishing. Pending improvements in the models used in these predictions, international efforts are now being made to restrict fishing on these species. However, it is recognized that the major production of fish protein takes place among the smaller fishes, and that a given weight of smaller animals probably has a greater capacity to graze food organisms than the same weight of larger animals. There is thus considerable doubt as to the sustainable yields of present commercial species under very different fishing techniques. Our knowledge of interactions and productivity of the biological communities as a whole is critical to fisheries management but is still very primitive. We know very little about the interdependence of fish species and sizes on their food supplies, little about the relative merits of different species as producers of protein, or of the conditions that control their successful reproduction. We do know, however, that there are significant differences in productivity among species, and fishing at present intensities does lead to changes in species "balance" of the ecosystems.

Canadian marine scientists are world leaders in the development of knowledge of biological and fisheries production. Canada must accelerate her progress in this field, however, in the light of her responsibilities with respect to fisheries resources under her jurisdiction, and in the light also of her special interest in the conservation and management of the major sea fisheries beyond the limits of her present exclusive fishing zones. Although present Canadian competence compares well with that of other countries, it does not fare so well if compared with the need. It is essential that we quickly develop a method of predicting the productive capacity of a given region of the sea if we are to formulate intelligent national and international fisheries policy. Continued efforts to this end are a major responsibility for Canadian marine scientists.

Phenomena at the Limits of Present Scales of Observation

While the majority of problems studied in marine science originated in association with readily observed phenomena, the science has developed to the point where it is possible to deal with variations showing very large and long, or very small and short, scales. Such studies are generally considered essential to the science, since it is in this stretching of the imagination and technical capacity that new concepts and generalizations arise, permitting new approaches to problems which often seem hopelessly complex and intractable from the level of initial observation. It is in this area that costs of research frequently rise rapidly, with consequent difficulties in finding financial support. This is true despite the repeated demonstration that in this area are often found the new technology and applications on which major industrial development depends.

Geological and geophysical investigations of the sea floor and land masses deal with such phenomena, and recent studies of the mid-ocean ridges have led to a revitalization of theories of continental drift. Such studies have generally been initiated by scientists whose chief motivation has been to understand how the earth came to be what it is. But it is equally important that, on these time scales, the mineral and oil resources that are generally classed as non-renewable become dynamic components of the system. Investigations of this scope have in the past led to new appreciation of mineral-bearing geological structures and of the processes and rates of change responsible for them. The history of practical results from this field of research is well known in terms of techniques for improved prediction of areas of occurrence of minerals and oil, and their compositions and concentrations. While such results are expected by sponsors of the research, the significance and probability of usefulness of associated phenomena can rarely be so predicted. The recent finding of concentrated hot brines overlying very rich mineral concentrations in what is considered to be the spreading zone in the floor of the Red Sea is an intriguing example. It has set off a host of speculations concerning possible economic recovery of minerals from similar zones in other areas of the world, such as the deep rift-zones off the British Columbia coast.

It was with the formation of programs in marine geology and geophysics at the Bedford Institute and Dalhousie University Institute of Oceanography some eight years ago that the potential of the Canadian east coast continental shelf for oil and minerals was first demonstrated. This work was directly responsible for the rapid rise in extensive oil and gas leases and exploration activities. Similar background work has been developed over many years in the Canadian Arctic by the Geological Survey, and more recently in water over the Arctic shelf by the Polar Continental Shelf Project jointly sponsored by several branches of government. It is a seemingly unique property in this area of research that, given the background research and requisite government financial incentives, private industry undertakes most of the detailed oil, gas and mineral surveys and explorations. In the Arctic, a Canadian company has undertaken one of the most comprehensive exercises in logistics and detailed geological survey ever undertaken by a private company, and at the present time there are encouraging signs of development of Canadian enterprise on the east coast continental shelf. Despite this, there is still a requirement for expansion of university and government research and survey efforts, for both the balance in public information it provides and the perspective it gives for the interpretation of local phenomena.

Up to the present, much of marine geological and geophysical work in Canada has been concentrated in the Atlantic and Arctic. Conditions in the Pacific are different and there is a clear case for extension of the programs to these areas.

On a rather shorter time scale, but of particular relevance to Canada, is the study of *glaciation*. In the past, most such work has been primarily concerned with the description of past events and the effects of glaciers on the superficial geology. It is only in recent years that biological, geological and geochemical studies of the continental shelves have revealed the magnitude of the effects of glacier formation and retreat on land and sea levels, on climate, and on biological communities. There is, furthermore, a growing appreciation of the possibility that such major events result from seemingly minor causes. This knowledge, linked with increasing evidence of the impact of modern civilization on our environment, makes theories and studies of glacier formation and long-term climate changes, which once sounded "academic", subjects of more than passing interest and concern to Canadians.

It is common knowledge that the consumption of fuels in our civilization has led to substantial increases in the fixation of oxygen and an increase in production of carbon dioxide. We must now pay serious attention to the *constancy of the composition of the atmosphere*. Important quantities of elemental oxygen are released by biological processes in the sea, and sea water has an apparently large capacity to absorb CO_2. Despite this, it is claimed that the CO_2 content of the atmosphere is increasing at a measurable rate and could, by its effects on heat-absorbing qualities of the earth, alter its heat budget. At the same time, some of the waste products that find their way to the sea inhibit the biological processes that must contribute to the rate of turnover of atmospheric gases. While it would take thousands of years for most of these processes to alter our environment materially, the interplay of long-term and short-term mechanisms in determining the present quasi-steady state needs to be known. It is certain that chemical events in the sea are importantly involved, but the present state of knowledge of even the most elementary marine chemistry is remarkably primitive. For example, it is known that many of the chemical constants used in laboratory handbooks are inappropriate to the dilute but chemically complex sea water. We have only begun to measure the composition, activity coefficients and partial volumes of the elements and ionic complexes in sea water. We do not understand such fundamentally important systems as the carbonate balance. (We once thought we did, but one of the consequences of our growing realization of the true complexity of the ocean has been destruction of much ill-founded confidence.) It is known that the composition of sea water differs from place to place in the oceans, but we have little knowledge of the significance of these differences. Our ignorance of physico-chemical events at the surface is rivalled only by our ignorance of events of the water-earth interface, where the further complexity of very high pressures is only beginning to be considered. While one of the most widely used manuals for the chemical analysis of sea water was prepared under the auspices of the Fisheries Research Board in the laboratories of the Pacific Oceanographic Group, and chemical oceanographic research of high quality is done there and in the Halifax-Dartmouth area, chemical oceanography is as badly neglected in Canada as elsewhere in the world. This neglect will be felt in our attempts to understand the impact of pollutants on the marine environment.

At the micro-scale end of the spectrum of scales of marine phenomena, studies are primarily concerned with *measurements of energy transfer* and an understanding of the mechanisms controlling it. Most of the energy derived from the sun is absorbed by the seas. An understanding of energy transfers at the *air-sea interface* is therefore basic to all environmental science. While the radiation energy at the sea surface is fairly well known, the fractions reflected from or absorbed through the surface, and the return flux from the water to the atmosphere, depend on a variety of factors. Sea state is of obvious importance. Waves at the surface result from the transfer of momentum from the air to the water. They influence the absorption of radiation. As they decay, the energy they lose to turbulence contributes to the mixing of absorbed thermal energy into lower layers of the sea. They are partly responsible for generating the ocean currents through which this thermal energy is redistributed. During this process energy is released in a complex fashion to the atmosphere, contributing a major fraction of the energy that drives the atmospheric circulation. Even the instrumentation required to measure exchanges at the air-water interface of this vastly complex and interlocking system is a major challenge to our technical and scientific abilities. On the results depends prediction of wave formation, currents and mixing. Much that is basic to prediction of both oceanic and meteorological conditions has been learned during the past five to ten years. Some of the most advanced work has been done in Canada and provides a strong base from which to enhance our knowledge of the problems that remain to be solved.

It is at this micro-scale that the energy transfers to the *food chain* with fixation of the carbon from CO_2 and evolution of free O_2 take place. These events are strongly dependant on physical forces at the surface. The currents and mixing processes have first to bring mineral-rich water to the surface zones where it is available to the primary producing organisms. The surface turbulence strongly influences the exposure of these organisms to light and is important in determining their distribution and availability to herbivores in the system. Turbulence has a strong influence on the subsequent rate of sinking of these organisms out of the photic zone. In recent years, it also appears that there are other important and unexpected events which may be of great significance to our notions of basic production. That is, the dissolved organic carbohydrates and amino acids, which probably result both from metabolism and from the death of the plankton, become aggregated again into organic particles which are available as food to the small consumers in the food chain. The discovery of this phenomenon has led to a completely new appreciation of the efficiency of transfer of energy throughout the biological food chain. The mechanisms underlying these aggregations are unknown but may involve microbiological as well as physical reactions. Some of the most striking features of the new discoveries associated with organic aggregates concern the uniformity and ubiquity of their distribution throughout the oceans, including the great depths.

Production processes in the sea have been studied by marine scientists for many years, and a number of methods have been evolved for measuring primary production. In several countries, notably the United States and Europe, careful studies have been conducted which have permitted good relative, though probably low, estimates of primary production. One of the aims of the research has been to relate these estimates to fisheries production. The results are still of questionable value, partly because there is still no satisfactory measure of production of the herbivores and other zooplankton. Curiously, for many years very little work in this field of biological oceanography was done in Canada except for a period of a year or two in the early 1930s. As a result, we still lack indices of even primary production in most of our waters. The filling of this gap was, however, begun about 15 years ago on the west coast, and there has been a substantial development of knowledge on the east coast during the past five years. During this recent period, scientists in the Canadian Government and university laboratories have evolved significantly improved instruments and techniques which permit better estimates and comparisons of productivity among regions. It now appears that we are approaching an understanding of the nature of parameters underlying measurement of secondary production. However, the present level of effort is far short of that required if we are to advance at a reasonable pace toward the objective of predicting the productive capacity of our coastal waters and bays, and of assessing the impact of pollutants on them.

The Technical Problems

We have pointed out above that advances in the sciences are interwoven with advances in technology. That is, when a variable is identified, there almost always follows a requirement for quantitative measurement which is dependent on appropriate instrumentation, and a suitable platform from which to work. Then comes a demand for analytic facilities and data storage. The initial results frequently call for modification of equipment designs and, subsequently, of the analytic system. The process is often a long-continued feedback system, interrupted only at those points where an opportunity is seen for exploiting a set of observations or a particular technique. The area of exploitation may or may not be related to the objectives of the original study program, and may frequently cause a shift in the original direction.

Instrumentation

Until recently, instrumentation in marine science has been primitive compared with that in other active sciences. In physical oceanography, devices designed 50 years ago by Ekman and Nansen are still in common use. In biological oceanography, many of the sampling instruments in use are basically the same as those in use in the 19th century. Partly this slow evolution reflects a traditional reluctance to use electronic methods at sea. A brief experience is often sufficient to demonstrate that electricity and sea water do not mix, and to show how very rugged the equipment must be to withstand the necessarily rough handling. But partly it has resulted from out past failure to appreciate the high complexity and dynamism of the three-dimensional marine environment compared with the relatively stable two-dimensional terrestrial environment in which we are used to living.

This situation has been rapidly changing in recent years. In at least the physical and geophysical sciences, techniques of measurement with sensitive instruments of advanced design are fully as sophisticated as in any contemporary science. While biological instrumentation has lagged, rapid advances are being made with the use of acoustic and tracer techniques. Laser techniques also show considerable promise.

In Canada, most marine instrumentation advances have taken place in the larger government laboratories, such as the Bedford Institute and laboratories of the Defence Research Board. There have also been significant developments at the Institutes of Oceanography at the University of British Columbia and Dalhousie and at the National Research Council laboratories in Ottawa. Some of this new equipment is still in the early development stages and its worth is difficult to judge. Some of it, however, is superb and gives the oceanographers possessing it a capacity unmatched in the world.

The major impetus for much instrumentation development has been in the Defence Research laboratories. They have, for example, developed particularly fine instruments for acoustic work at sea and for measuring the microstructure of sea water. The towing systems–we use the word advisedly in the full contemporary sense of systems engineering–which have been devised put to shame most other techniques used, either in Canada or elsewhere. The professional and technical expertise that went into these developments is still mostly with the laboratories. Recently, however, the defence interest in at least parts of these fields appears to have waned, although the methods and equipment evolved are still of the greatest importance to the science, and have a number of potential applications or even commercial prospects in the civil area. Special measures need to be taken to ensure that the potential advantage conferred by this large initial investment in money and brain power is not lost. Where defence interests have truly changed direction and the civil interest is demonstrated, these programs should be transferred to the civil sphere rather than terminated. Some transfer of personnel might be desirable. Certainly there should be dissemination of the necessary skills.

The development and use of equipment is expensive, time-consuming, and requires special engineering skills. There seem to be two special problems associated with this fact in Canada. The first is that, while marine science is more dependent on special equipment, ships and computers than most science, the ratio of capital to operating funds allotted to it appears, as far as we can judge from available data, to be almost the same as the allotment in other sciences, i.e. about 30 per cent. It is our opinion, based on considerable scientific experience, that a relative increase of capital funds for equipment development is an important requirement for advancement of marine science.

A second remarkable feature of the marine instrument field in Canada is the lack of participation in it by the industry. This is partly a result of the low level of capital expenditures which leads laboratories to acquire expensive machines "in-house" in bits and pieces over rather long periods of time, modifying and developing as they go. A second factor is that the major industries and technical competence in the country are inland and show little interest in the sea. Canadian scientists' contacts with potential suppliers are then mostly with foreign agents who, besides their selling activities, are constantly alive to the possibility of new products based on developments in Canadian laboratories. But whatever the cause, a significant number of instruments developed in Canada have never been manufactured outside the laboratory that conceived them, and are thus not available to their fellow scientists. This is not the general case elsewhere in the world. Failure to take special measures to develop an active liaison between the science and the manufacturing capability is both scientifically and economically wasteful.

The present situation is exacerbated by present government bidding practices. Frequently, at the expense of much time and effort on the part of both the government laboratory and the industry, a good working arrangement is evolved between government scientists and a particular firm for the production of a particular device or class of devices. However, when that program ends and another is begun, government practice calls for a new round of bidding and frequently a completely different company is brought into the picture. The whole operation of mutual familiarization must start again from scratch. The process not only seems wasteful of time for the laboratory worker, but does not appear to have developed any real degree of independent marine technology among the many small industries which become involved at different times. There may well be a case for a policy of "chosen instrument" in which firms are given special rights, subject to continued good performance, to operate in co-operation with a particular government laboratory.

Deliberate policy should make it possible to break the circle that leads to the separation of engineering expertise in the laboratory and the manufacturing capability in industry. A first step should be a general increase in the level of spending by both government and universities on the development and acquisition of equipment. A second important development, which is needed in marine industrial development generally, is encouragement of ocean engineering, including engineering research (oceanology) in selected Canadian engineering schools. At the same time, some thought should be given to closer linking of industry and research laboratories, which could probably best be done by placing industry engineers and scientists in laboratories that have the in-house expertise, possibly with government assistance, as a kind of special training program. In the case of "chosen instrument" industries, the relation should require a guarantee that after an initial period the industry would retain professional staff of its own. An essential additional step must almost certainly be a more generous support of industry research, development and innovation, by a combination of devices. The opportunities for more frequent use of contracts by university and government laboratories should result from the liaison mentioned above; in addition, there is probably a case to be made for greater government sharing of risk costs in many instances, sometimes to the extent of fully funded development contracts. Finally, there must be a vigorous and well-informed sales program–surely an industry responsibility. In Chapter VI we discuss mechanisms that are required by such a program.

Ships

Research ships are designed primarily to be stable platforms from which oceanographic sampling may be done. However, as the science becomes more sophisticated, the designs for the platforms become more and more specialized. A most important requirement is for high-precision station keeping, often in very rough weather. Special deck equipment is needed for handling the large heavy instruments over the side or through the hull. So also are new winch designs and cables to permit the sampling gear to reach great depths, and operate at fast towing speeds. There are needs for more and more sensitive under-way control, special wiring and stable power supplies for sophisticated sensing devices and on-board computers, or particular noise characteristics to permit the use of acoustic devices. This growing requirement for specialized designs and equipment calls for an increasingly close relationship between the builder, designer and research user in the development of research ships.

According to information made available by the Canadian Committee on Oceanography, the present fleet of Canadian "scientific" ships is no fewer than 26 vessels over 70 feet in length, including the 2 west coast weather ships and auxiliary vessels supplied by naval forces, but not including some 13 icebreakers. About half of these 26 ships are large vessels of over 200 feet. This is a sizable fleet; indeed, enough to form the basis of an industry.

A number of these vessels are conversions, but in recent years several specially designed research ships have been constructed. These new designs are far more suitable to their purpose than the conversions. In the future, still better designs will be conceived. New concepts in hull design, manœuvring capability, stabilizing equipment and working arrangements have been attempted both in Canada and elsewhere, but there remains room for much improvement. For example, the basic needs for a "dry" ship and for very low freeboard in a working area are conflicting. No fully suitable compromise has yet been found. The demand for stability is so great that scientists have been led to consider very unconventional designs, or even the use of large submersibles of the navy type, as research platforms. Few of these ideas have ever been tried.

Ship design remains largely an art rather than a science, and improved designs will only evolve by trying out ideas. When the research ship *Endeavour* was designed for the Defence Research Establishment Pacific, some new concepts were used. Some of these proved to be failures. Nevertheless, these failures should not be allowed to discourage further innovations. Never to fail is a clear symptom of overcaution!

Designs should be encouraged to evolve. Optimization of their evolution requires close co-operation between designer, builder and user. In particular, the designer needs strong inputs from the user concerning the strengths and weaknesses of previous designs, as well as information about new kinds of uses to which the ship may be put. The builder needs to be able to point out to both the user and the designer changes in plans that might make construction cheaper or easier–and to learn whether such changes would importantly affect performance. The designer needs to be able to point out to the user new concepts that can be tried–and to learn from the user if these concepts meet any need and, later, if they worked.

If we were to adopt the view that the typical service life of a scientific vessel for Canadian use should be only about 15 years, simple replacement would require the construction of nearly two ships per year, and future expansion would bring this figure surely to at least three. To this could be added one icebreaker every year or two. If these facts were recognized, it would then be seen to be reasonable to develop a full-time ship design team, specializing in scientific vessels. Such a design team, given suitable feedback, should be able to achieve improvements in research ship design such that by the time vessels reached their 15-year retirement age they would be obsolescent, if not totally obsolete. The obsolescent vessels need not be sent to the wreckers. They can find a use in the less-developed parts of the world.

Further, this design team could develop a special expertise which would enable it to seek export orders. None of the European countries, nor Japan, has so large a research fleet, although world demand is high and oceanographic efforts expanding. Only the United States and the Soviet Union at present have large research fleets and major construction needs. Thus, the chief arguments against Canadian participation in the world's shipbuilding efforts, e.g. high labour costs, are less applicable in the research ship area. Such handicaps apply *a fortiori* to the United States. As for the Soviet Union, she is as yet far behind, and there is no reason to believe that she need be allowed to catch up. Although she has a very large research fleet, virtually all of her vessels have been built in East European yards, and the feedback between user and builder is small. Our vessels are, and can continue to be, systematically better. Provided that Canadian marine science remains of high quality, we should be able to provide specifications for scientific ships superior to any competitor. Thus, with a design team and building program to back our own oceanographic effort, there is no reason why we should not be in a strong position to market specially constructed research vessels. The opportunity should not be neglected.

If we are to expect foreign sales, it will be necessary to promote them by demonstrating that Canadian-built research ships can serve an economic purpose. As part of this demonstration, and at the same time to fulfil a vital and important responsibility in the field of foreign aid, Canada could build one or more intermediate-sized research vessels which would be specifically assigned by Canada, and operated by Canadians, to carry on survey work for underdeveloped nations. One such ship might well capitalize on our knowledge of techniques and equipment for combined hydrographic and geological (especially geomagnetic) surveys of harbours and shelf areas in developing countries. The work should include the preparation of charts requested by the country and the training of local crews, technicians and scientists. The second ship should be a marine-biology-fisheries and oceanographic survey trawler.

The development of an industry which would at the same time supply Canada with better designed and more efficient research vessels involves surmounting some administrative hurdles. Because the building of a research vessel is regarded as an unusual event, there are few scientists in research agencies in Canada who ever give the matter serious thought until faced with the prospect. Even then, present government administrative procedures assign design and purchase authority to a central government agency, the Department of Supply and Services, backed by private consultant firms. From the user's point of view this agency does its work well, considering the frequently unprepared state of the user to specify design implications of their operational requirements. But the policy appears to have removed the shipyards themselves from a knowledge of the directions of new developments.

This appears to result not only in serious constraints on production of new ship types, but in an inability to redesign the shipyards and co-ordinate production procedures including skilled labour requirements for improved efficiency. In our view, improved longer range planning and better communication between user, designer and builder are needed. This might be accomplished by:

1. Formulation and announcement by Government of longer term research ship-building policies, perhaps for five-year periods, rather than as individual decisions;

2. Designation of at least the most favoured regions and possibly the most favoured yards for awarding of long-term contracts for design and construction based on standards guarantees;

3. Development of a system of total procurement contracts with shipyards, with the aim of increasing the liaison between designer and builder;

4. The setting up of a committee of scientific users to act in concert with builder-designer teams to forecast trends in the user requirements;

5. Study of the possibilities for a system of private or "separate agency" ownership and operation of Canadian research vessels. The aim would be to have the private owner make the vessel of new design available to government and university users on the basis of a guaranteed long-term charter. But at the same time, the private owner would be able to combine government with private industry contracts and to seek foreign sales, enabling a more rapid turnover and evolution of research vessel design. There are indications that this system of operation would, at least for certain vessel classes, result in substantial savings. This concept is developed in Chapter VI.

Data Centres and Computer Facilities

It was noted previously that a basic requirement for marine science, as for all environmental science, is description of the system. However, the acquisition of data at sea is expensive, so that maximum advantage should be taken of all such acquisitions. Typically, a scientist gathers in the course of his investigations data useful for purposes other than his own immediate one. In his analysis it is frequently important to have comparative information on areas, situations and times other than those covered by his own field work. These constraints and needs led very early to various forms of data compilation and exchange, and finally by the late 1950s, resulted in formation of a number of National and International Data Centres, charged with the function of collecting data from many different users, processing it into standard form, and storing it for retrieval and exchange. There are still many technical problems associated with this process, but improvements are being made steadily in such areas as standardization of the quality of input, usefulness of format, creation of new standards and methods for handling such difficult areas as biological data or the continuous profile analogue data from new instrumentation.

Although many scientists had initial doubts as to the quality of information that might be handled by such large and anonymous systems, the data centres are gradually winning acceptance. For example, the Canadian Oceanographic Data Centre, established in 1964, in 1965 had submitted to it for processing the data from only about 6 000 oceanographic stations. In 1968 this number had risen to over 25 000. In 1967 it submitted data on 940 stations to the U.S. National Oceanographic Data Centre and obtained data on 4 500 stations. It had domestic requests for data on about 5 000 stations. In 1968, exchanges with the United States were 2 100 offerings and 6 000 receipts, and there were domestic requests for data on about 10 000 stations. These numbers refer only to physical oceanographic data. In addition to the oceanographic data centres, there are in Canada data centres dealing with geological information and weather information. Recent steps have been taken to develop methods for handling information concerning ice, with particular reference to navigable waters. There is a use for similar information on fisheries. Data centres have, in fact, fast become essential to the scientific user. For example, it was with the establishment of World Data Centres in connection with the International Geophysical Year, 1957-58, that it became possible for the first time to carry out investigations of physical phenomena of the earth on anything like a planetary scale. There is no doubt of their continuing and increasing importance.

Data centres were originally set up to meet the needs of scientists. The satisfactory performance of their function depends on clear identification of the users, and definition of the uses to which the data can be put, since it is the use that largely defines the form of storage and output. Much of the continuing work of the centres consists of redefinition of this use as there develops the need for investigation of new phenomena on different space and time scales. But as development of the science has shown new opportunities and responsibilities for use and management of the sea and its resources, a new group of users has begun to take an interest in the data banks. These are the marine industry and government managers. This change in the purposes for which data can be used poses new problems for the national data centres.

The first problem concerns the sources of data for the data bank. The scientist's first motivation is usually that of finding out how things work. It is therefore a rare scientist who does not hope that his results will be applicable as widely as possible, not only in general science but in the world at large. With personally collected scientific data, his interest in it is that he should process it to establish its validity and, where possible, at least some aspects of its significance before it is released for public use. The question arises: "How much study and processing is appropriate?" He is obliged to judge this for himself in his own special field of competence. But how far can and ought he go in the interests of other users? In general, the growth of input into data banks implies acceptance of the principle that he should make his own data available to the bank as soon as he has established its validity and has put it in a form useful for exchange in co-operative international programs. The returns of exchanged data from other sources make this approach well worthwhile for the individual scientist and appear to contribute substantially to the efficiency of research.

The motivations, hence requirements and methods of operation, of industrial users are different from those of scientists. In the first place, industry, especially the oil industry, is carrying out substantial survey work of its own. The geological and geophysical data accumulated are of use to the science but are also useful to possible competitors. Satisfactory methods for handling and disclosure of geological core information have been worked out. Attention needs to be given to arrangements whereby the geophysical and other oceanographic information collected by private industry could be added to the data banks.

The second problem associated with industrial users of the banks is concerned with use of data. The problem is of particular relevance and is almost unique to Canada. Much in marine technology is new, and much of the Canadian industry associated with it has rather narrow experience. In many cases there is virtually no independent research competence and a weak technological and engineering base. In this sense, Canadian industry is in a disproportionately disadvantageous degree of readiness to seize and make use of opportunities available through the scientific finds, *vis-à-vis* U.S. (and in some instances U.S.S.R.) interests. While analogies are dangerous, the situation with information exchange has been revealingly compared with the exchange of privilege between two men, one having a small pasture and 100 cows, the other with a large pasture and 1 cow. The nature of the mutual advantages of such an exchange is one which must be squarely faced in policy concerning the exchange and use of scientific data. It is clear that international exchange is one of the cheapest and most efficient means of collecting oceanographic data (c.f. statement of Dr. T. Austin, Director of the National Oceanographic Data Centre, Washington, D.C., before the U.S. Congressional Committee on Merchant Marine and Fisheries). Any inhibition of free exchange would have a serious effect on scientific advances and should be protected by international agreement. However, a system set up for science is not necessarily readily adapted to industrial use. The implication for Canada is that special efforts must be made to create, within the Canadian industry, groups who can identify and learn to make practical use of the vast amounts of information available to them. We return to a discussion of this problem in Chapter VI.

Chapter IV

Challenges, Responsibilities and Opportunities

The Biological Resources

The Sea Fisheries

It has often been pointed out that, on a world basis, fisheries produce the most important product which is taken from the sea, and that they yield a vital proportion of the world's total supply of animal protein food. In fact, the present world catch of some 65 million tons represents 18 per cent of world animal protein consumption.[1] World catch has been rising steadily at a rate of about 7 per cent per year, appreciably faster than world population (Fig. IV.1). As a result, fish catches have contributed very importantly to the rise in world per capita food supplies during the past decade. (Fisheries increases represent a rise of about one third in the production of food per head![2]) A further aspect of fisheries is of great importance to developing countries. Some of the major concentrations of fishes now being exploited, and some potentially rich but as yet untapped areas, such as the Arabian Sea, the sea off West Africa and off eastern South America, are close to their coasts. However, high-seas fishing is a technologically complex business and many such countries do not yet have the resources, knowledge or management skills they need. On the other hand, some of the more advanced nations such as Japan and the U.S.S.R. have world-ranging fleets, and these are rapidly growing.[3] One of the reasons for this continued great interest is that fish represent by far the cheapest and most accessible forms of balanced protein food. All known cheap vegetable sources require supplements.

While Canada ranks among the top ten most important fishing nations of the world, she plays a very small direct role in the provision of world food supplies of fish. It is fair to say that Canadians are essentially fishing for dollars. Our major exports in terms of value are to the United States and Western Europe, although in time this situation could change radically with the advent of fish protein concentrate (FPC) which is easily shipped and stored.

Because of our present situation, our concern must first of all be with the economics of fishing, except where we are technologically advanced enough to assist needy countries to develop their own fish-catching and fish-processing industries, or where we have other important international responsibilities (Chapter V).

Economists are not agreed on how to evaluate fisheries. In terms of overall Canadian Gross National Product, they are almost inconsequential (0.6 per cent 1968). In terms of exports, they vary around 2 per cent of the total value, compared with about 4½ per cent for oil and gas, and between 5 and 12 per cent for wheat. In terms of net export value, they yield about $200 million in a total positive balance of trade of around $450 million (1966 data, *Canada Year Book*, 1968). Clearly, they cannot be neglected.

An important reason for the difficulty of economic evaluation lies in the complexity of the industry. Fisheries are not *an* industry but an amazingly heterogeneous collection of enterprises, varying in size from the truly rugged individualist with a small boat, a hand-line and a bit of clam or squid for bait, through the rather larger salmon fishing boats of the west coast with strong labour union organization of crews to bargain with the canneries, to the million dollar offshore trawlers operated by the large, efficient, vertically integrated fresh-fishing industries of the east coast. The economic importance and vigour of the fisheries show correspondingly great regional differences.

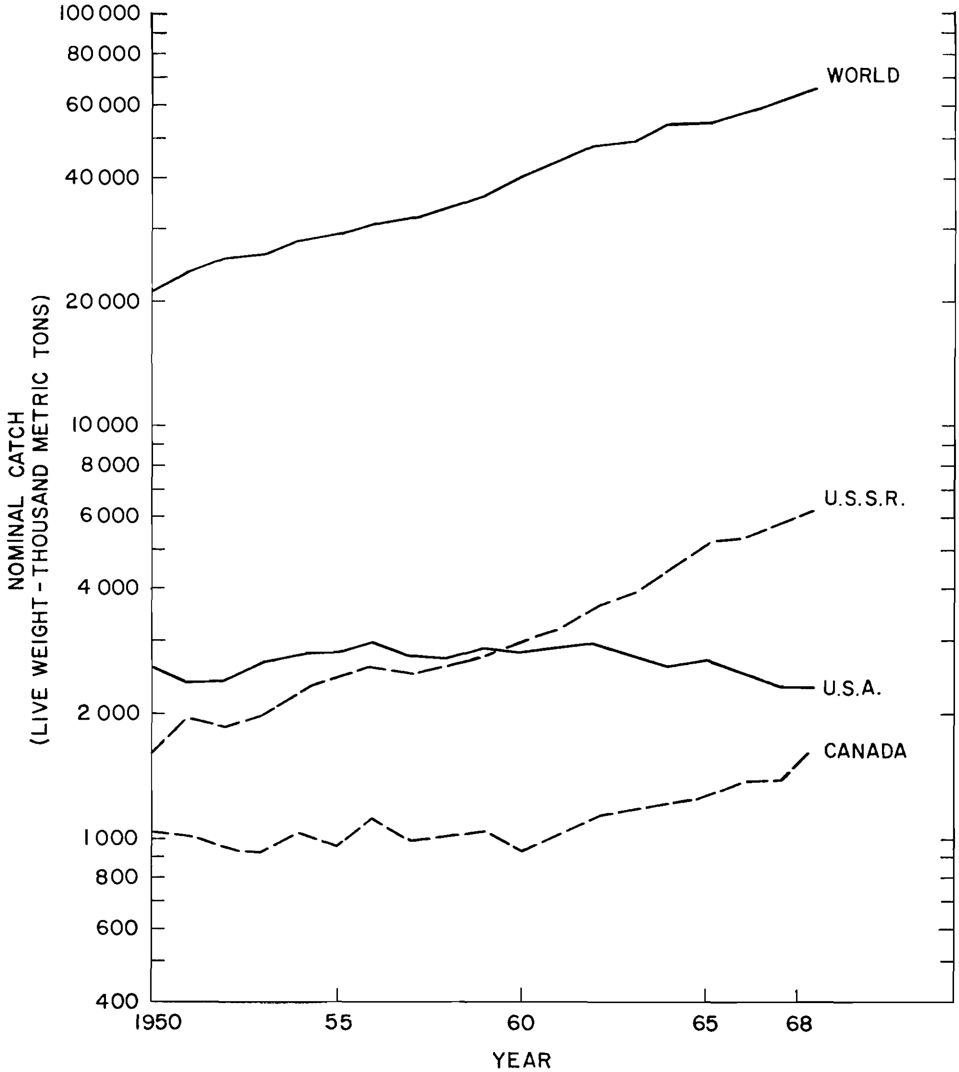
Probably the greatest economic impact of the fisheries is in Nova Scotia, and this situation is worth examining since it

[1]Global Ocean Research. Report of a joint working party of the Advisory Committee on Marine Resources Research (FAO), the Scientific Committee on Oceanic Research (ICSU), and World Meteorological Organization (WMO), Ponza & Rome. Published at La Jolla, California, 1969.

[2]Food production–shortage to surplus. Nature, 225: 9. 1970.

[3]The Japanese now fish off West Africa and have recently conducted trial fishing on the Grand Banks. In the Northwest Atlantic, the U.S.S.R. now takes the second largest catch, more than half the total catch of Canadian east coast fishermen.

Figure IV.I-Fish Catch



illustrates what can be done. In the first place fisheries are a highly important part of the economy of the province (about 10 per cent of Provincial Product), and have shown a small but steady relative increase during recent years. The rate of increase in offshore fishery landings has averaged 7 to 8 per cent by weight and over 10 per cent by value. The catch trends in recent years have at least equalled the world average, and except for the U.S.S.R., equalled these of other countries fishing the Northwest Atlantic.

This picture of expansion has not always been the case. Prior to about 1960, increases in catch and value were slower (Fig. IV.1). The present trends resulted from a government policy for fleet renovations, replacing outdated and inefficient ships with modern trawlers. What is clear from the result is that fishing in this area is not at present limited by the size of the resource, but rather by economic considerations.

A second factor of importance is that, in a recent study of trawler performance by the Fisheries Research Board, it was found that the catch per day by our vessels was greater than that by any of the comparable-sized European (14 countries) or U.S. trawlers, except possibly for the Spanish vessels. While exact crew sizes are unknown, Canadian catch per man per day appears to be the highest. Furthermore, Canadian vessels fish more hours per year than do vessels of other nations. Evidently the eastern Canadian fleet can catch its "share" of the total in the highly competitive situation off our east coast.

A third feature of importance is that the processing industry is also modern by most standards. In fact, productivity per man employed in fish plants has been slowly but steadily rising as a direct result of new investments in plant renovation.

Finally, it is of considerable importance that in the fishery the cost of materials–of the landed fish–is of the order of 70 per cent of the total cost. This cost is not only high, but rising, tending to squeeze the gross margin of the enterprises.

Overall, the Nova Scotia offshore fishery is an economically vigorous and modern industry. This situation has not been achieved without considerable industrial innovation and effort. Over recent years the number of species caught, and for which new processing methods and new marketing methods had to be developed, has increased steadily. The most dramatic new development has been a very large increase in the production of herring. Furthermore, with attention to modern merchandising practices, the quality of products released to the consumer has shown steady improvements and correspondingly, fish consumption by North America is growing faster than population.

The immediate prospects for such an industry are bright, but not without difficulties. It is clear that Canadian catches can be increased still further, should we so choose. Our present east coast catches are made only on the southern parts of our continental shelf. Furthermore, quantities of species which are not yet utilized are known to exist in some areas. However, it is clear that increases cannot continue indefinitely. Natural fish population productivity is limited. It has been estimated that with present trends and no major changes in fishing technology the overall catch of the Northwest Atlantic could reach a maximum in some 15 to 20 years. This length of time is well within the expected lifetime of a new ship. It is therefore essential that, as a guide to economic planning for these fisheries, marine science and technology make every possible effort to measure the potential productivity of the waters over our continental shelves. Present methods do not allow us to make estimates which are accurate even within an order of magnitude. Such estimates are obviously of little use in economic planning.

A further problem exists in relation to the economic yield of fisheries. Past experience has shown that as the total catch of a particular species increases, the yield per unit of fishing effort decreases and the catch may be expected to tend to an asymptote. This situation has been reached on the east coast already with the larger sizes of some species such as cod and haddock. Hence increased effort tends to make fishing more and more expensive. Where alternative species are not available, or where fishing methods and markets are too inflexible to utilize them, economic waste of fishing effort results. Much of current international fisheries negotiation is now concerned with the problem, and countries which do not have modern fisheries are bringing considerable pressures to bear with the purpose of restricting the total amount of fishing. Even where alternative species and markets exist as they do in Canada, there is a clear danger that production costs may start to rise more rapidly than do production costs in the country generally. Such situations demand forthright economic controls taking the biological state of the fishing areas into consideration.

In any case, there is a clear requirement for increases in the efficiency of fishing. Great strides have been made in this direction in the last decade in eastern Canada. Moreover, in the Nova Scotia fishery, the ratio of increased capital investments in the fishery to the annual dollar yield of products is of the order of 2. In modern technological industry generally, a value of approximately 3 is accepted as normal. On this basis, it would appear that further capital investment in modernization for increased efficiency is justified. Two avenues would appear fruitful. The first is a development of the "searching" efficiency of fishing vessels. Modern acoustic techniques have already been adapted to fish-finding and are used to good effect in some instances. However, quantification of the "echoes" from fishes is still in a rather primitive state, and as yet virtually no progress has been made towards increasing the effectiveness of fish searching by developing fishing-fleet strategies. The second avenue is an improvement in the fishing methods themselves. This is a very difficult undertaking involving a knowledge both of fish behaviour and of the operation of the catching gear and the machinery which handles it. Little work of either type has been done in Canada in the past. The present situation of the fishery would, however, appear to justify research in both of these scientific and technological aspects.

An important trend of modern technology is away from the labour-intensive towards the capital-intensive industries. The requirement for technological developments in this direction in fisheries will be much accelerated if, as we expect, there is an early development of the oil and gas industry on the coast. Fishing vessel automation should be seriously undertaken in the near future. There would be a significant export as well as domestic market for such systems.

It was pointed out that the situation outlined above applies primarily to the offshore Nova Scotia fishery. It may also fairly be used to describe parts of the Newfoundland, Prince Edward Island and Quebec fisheries. However, in these provinces, costs are higher, partly because of the winter ice conditions which inhibit fishing for several months each spring and partly because of high transportation costs. Furthermore, in all the provinces, especially Newfoundland, there exist rather large numbers of inshore fishermen with primitive equipment. These men do not share the generally profitable, if arduous, life of the offshore fisherman.[1] Rationalization of the fishery in this area is a prime concern fraught with very great difficulties, including a shortage of capital for investment in modernization.

The situation appears somewhat similar on the west coast, although with many different aspects, some of which stem from the fact that fishing is primarily devoted to the very lucrative salmon fisheries. Fishermen's incomes in this province are higher than in eastern Canada. But the vessels and equipment needed to enter this fishery are relatively inexpensive. The result has been too many boats,

[1]The 1967 average annual income of a full-time fisherman in Newfoundland was $1 368 compared with $2 945 for the Maritimes and Quebec. In British Columbia it was $4 068. These data are averages for all fishermen–inshore as well as offshore. (M. Daneau, background study prepared for this report.)

in effect an overcapitalization in the primary industry, with consequent economic inefficiency of manpower and resources. Unfortunately the fishing equipment is not well suited to fishing for other species, and until there is a "breakthrough" in new culture methods by which scientists are attempting to increase salmon runs, the yield of these fisheries is already at its upper limit. Rationalization of the fishery is as much a concern in Newfoundland.

In addition there are two other features peculiar to the British Columbia situation. The first is that there exists on the coast a number of potentially lucrative fisheries pursued vigorously by Japanese, U.S.S.R. and to a lesser extent U.S. fishermen. Canadian fishermen play little or no active role. The second is that with generally high living standards, rather dense urbanization, and a body of rather sheltered water, sports fisheries have been rapidly developing in salmon. The economic value of the sport fishery can be decidedly greater per fish caught than if the fish are commercially harvested and sold as food. It appears that the future development of fisheries for those species, which are liable to be captured by anglers, will be dominated by recreational developments.

New Marine Products and Methods

During the recent years there have been decided changes in the pattern of use of marine fishery products. Some traditional luxury items such as lobsters, oysters and fresh salmon have increased greatly in value relative to more "staple" items. To this we can now add shrimps, queen crabs and scallops. Furthermore, a far greater proportion of the catch of other species is now used for stock and poultry feeds. Before World War II, 10 per cent by weight of the world catch was turned into fish meal. By 1967, the proportion was over 50 per cent. On the other hand, the consumption of fresh-frozen fish has grown from zero to 12 per cent. The variety of food items has become much greater and the prices diverge widely. In addition new products have been added. Seaweeds, which grow most abundantly in the cool temperate waters of our coasts, are the source of a variety of food and cosmetic additives and pharmaceuticals. This area is one which offers great prospects but for which Canadian industry is not yet well equipped. For example, there is a rapidly growing east coast primary industry for harvesting seaweeds but these are exported in unprocessed form. The present economic value of this industry to Canadians would be more than doubled by development of a processing industry. Government marine science and technology efforts should be directed to assisting industry to undertake this task (see Chapter VI).

Perhaps one of the most attractive new fields, however, is estuarine or bay culture. Shallow estuaries and bays, such as abound around the Gulf of St. Lawrence, on the shores of Newfoundland and Nova Scotia, or along many parts of the British Columbia coast such as Berkley Sound, may be readily adapted to the farming of luxury items. This is not a pipe dream. One Canadian company is now commercially producing salmon in Nova Scotia entirely by culture methods.[1] Production plans call for an output of 6 million lbs. per year. Sales are about evenly divided among Canada, the United States and Europe. This development was carried out almost exclusively by industry, using known methods and government scientific advice. There is little doubt that many other opportunities exist for farming oysters, lobsters, crabs and a multitude of fishes, many of which need not be native species. Recent transplants of oysters, salmon and lobsters demonstrate that species can readily survive in conditions outside their native habitat. More recently scientific investigation of the possible culture of seaweed has been started in Canada.

There is room in these fields for considerable industrial development based on a backlog of relevant scientific investigation. Effective means need to be found to

[1]Sea Harvest & Ocean Science, Feb./March 1970, pp. 12–19.

make these opportunities known to Canadian businessmen and efforts made to develop producing industries. Successful ventures will need increased support of government-sponsored scientific efforts in the area of disease control and in the production of genetically superior strains. At the present time, very little scientific effort is in these directions, partly because Canadian industry does not yet recognize the economic potential which exists. However, the research is exacting and some of it long term. It should be supported more vigorously now in anticipation of the demand.

Uses and Abuses of the Environment

The flowering of public awareness and concern about the impact mankind is having on the environment is one of the most striking events of our age. It is a harbinger of the attidudes of the post-industrial society. Politicians everywhere have been caught unaware, and in places their discomfit at being subjected to these unanticipated public pressures is only too visible. Few industrialists have yet really appreciated the degree to which standard of living and quality of life are no longer being viewed as matters of goods and services. Economists are still struggling–without as yet much success–to incorporate the values of clean air, pure water and golden silence into their calculations of costs and benefits.

Some departments of government have begun to play an active and commendable role in generating an informed public opinion. (In our system of government, neither the politician nor his departmental officials can act effectively without it.) Those scientists deeply involved in study of the environment–ecologists, meteorologists, oceanographers and the rest–have generally rejoiced at the sudden public awakening (and–dare we say it–of their own increased sense of importance). At the same time they are dismayed at the number of questions they are being asked which they have insufficient knowledge to answer. Unfortunately, some scientists have taken advantage of this low level of knowledge to become prophets of doom–assured that although the evidence to support their jeremiads is thin or non-existent, there is at least no solid evidence to prove that they are wrong. It is difficult for the general public to distinguish between these self-appointed prophets and the responsible informed individuals who earnestly attempt to galvanize authorities into needed action on real problems, some of which have become serious through our past inaction.

The general state of ignorance is, of course, associated with the fact that environmental studies have not in the past been heavily supported at either the federal or provincial levels of government, and so have not been pursued with the intensity they deserve. But it is also associated with the fact that they are immensely difficult. The ignorance will not be dissipated soon or easily.

Radiation Balance of the Earth

The immense complication of the problems facing the environmental sciences can be illustrated in terms of the important problem of the radiation balance of the earth.

The present mean surface temperature of the earth is around 288°K (59°F). Its stability is dependent on the present balance between the way total energy is radiated into space by the earth and the proportion of energy from the sun absorbed by the earth. A change in either will result in a new temperature equilibrium, higher or lower than the present one.

A 2 or 3 per cent drop in present surface temperature (Kelvin) would set the great glaciers again marching across our land. A 2 or 3 per cent rise could cause extensive melting of the Greenland and Antarctic ice caps and produce an overwhelming rise in sea level. Both conditions have occurred before in the earth's history. Either could occur again.

The radiation balance which largely determines this temperature depends upon a great many things. First, and probably most important, is the albedo–the proportion of incoming sunlight which is reflected off to space. The albedo depends upon many things, chief among them being the cloud cover, as is abundantly clear from the magnificent photographs now available from space. However, there are other things of far from negligible importance. Clean snow is the outstanding example. From a radiation point of view, snow is powerful stuff. It is almost white in the visible, hence reflects most of the sun's incoming "light" radiation. It is almost black in the infrared, hence radiates "heat" vigorously.

Perhaps next in importance to the incoming solar radiation is the absorption by atmospheric turbidity–the dirt in the air. Some recent studies credit variations in turbidity, mostly derived from volcanoes, with causing the climatic changes which have occurred in historical times.

The behaviour of outgoing radiation is of equal importance. It is very strongly affected by the "green-house effect", produced largely by carbon dioxide. Carbon dioxide is transparent to almost all of the incoming solar radiation but, like glass, inhibits the outgoing infrared radiation, and so tends to retain heat near the surface.

The activities of man affect all of these things. High-flying aircraft add water vapour from burnt fuel at levels where the natural concentration of water vapour is very low. Clouds form which would not otherwise be there. These aircraft, and all kinds of industrial activity, add to the murk of the atmosphere and so reduce the radiation which reaches the surface. On the other hand, this same dirt, when it comes down with snow, reduces the albedo when the snow surface has melted somewhat.

Fossil fuels burnt by man produce great quantities of both dirt and new carbon dioxide. On the other hand, the eutrophication also produced by man results in a withdrawal of carbon dioxide. There is some evidence that pollutants, such as DDT, in the ocean act in the opposite direction. Changes in agricultural practices also significantly affect the release and absorption of carbon dioxide (as well as the albedo). The ocean contains about 60 times as much carbon dioxide as does the atmosphere, and so would be expected to greatly reduce the impact of influences on the carbon dioxide content of the air. However, much of the ocean seems to have a time constant of the order of 1000 years and so may be unable to take up its share of the additional carbon dioxide load in a time short enough to compare with the rate at which we are creating it. Because of the large number of these influences, and because of important gaps in our understanding, the observed rate of increase in carbon dioxide content of the air cannot be accurately and confidently explained by our existing knowledge.

It is not clear whether the mix of man's present activities is now tending to increase or decrease the surface temperature. It is even less clear what would be the effect of a different mix. We cannot appeal to observations of the changes in the earth's surface temperature (which has been somewhat downward in the last couple of decades following a systematic rise over the preceding century). The atmosphere-ocean system seems capable of producing, all by itself without man's interference, larger fluctuations than we have seen recently. Nevertheless, the habitability of our planet, and in particular of our country, depends upon the radiation balance. We are clearly *able* to affect it. We should know what we are doing.

It will not be next year that we will reach the necessary level of knowledge. It will take time, effort and money–and international co-operation. Fortunately for each of the sciences we are concerned with here–marine ecology, meteorology and physical oceanography–the research required has multiple uses and every small advance will bring its own reward long before we achieve the overall understanding which must be our objective.

As marine ecology advances, so will the ability to optimize regulations governing the conservation of fish populations. So too will information about the effects of pollution and how to minimize them. As meteorology advances, so will the ability to make reliable forecasts. Since it is at present estimated that the benefit-cost ratio of weather services is of the order of twenty to one[1], expenditure leading to improved forecasting can be expected to be fruitful. As physical oceanography advances, so will the predictability of marine conditions important to such diverse interests as defence, ship routing, ice forecasting and fisheries.

These are not *specifically* Canadian problems, but they are Canadian problems. Canada has at least as much interest in the solution of most of them as has any other country. She has made, and should continue to make, her contribution. In most, although perhaps not all, cases this contribution can be made through programs which also are a direct Canadian concern.

Environmental Studies on the High Seas
Compared with those of any other country with a high level of oceanographic competence, Canadian oceanographers have spent a far smaller proportion of their time and effort on wide-ranging expeditions far from our shores. In view of our limited human and financial resources, relative to our large coastal responsibilities, this situation is understandable and will probably continue. Nevertheless, for several reasons there should be an appreciable Canadian participation in deep-sea oceanography. Most important is the fact that waters on the Canadian shelves cannot be adequately studied except in the context of the influence of the oceans of which they form a part. Overlapping this is the fact that oceanic processes are taking place in regions not far from our shores which are of the very greatest importance to the behaviour of both the ocean and the atmosphere. Some of the problems which must command the attention of Canadian oceanographers are the following.

[1]Daneau, M., background study prepared for this report.

1. The tail of the Gulf Stream and of the Labrador current. Oceanographic theory has been moderately successful in describing the way in which ocean currents become concentrated on the western sides of the oceans. It has been far less successful in accounting for the way in which these concentrated currents break up and move eastward. It is known that regions where this takes place are subject to extreme fluctuations of all oceanographic parameters, and that vigorous mixing takes place. Such regions tend also to be associated with major fisheries. One of the most important of these regions occurs southeast of Nova Scotia and south of the Grand Banks. This is an area of obvious Canadian concern and demands the attention of oceanographers in the Halifax-Dartmouth area.

2. The thermo-haline circulation. Although most of the surface currents of the ocean seem to be wind driven, some of the most profound and important effects result from the ocean itself behaving like a heat engine. Water is cooled at high latitudes, sinks, and flows at depth to fill all of the great ocean basins. In a way which is not yet well understood, this deep water mixes with sun-heated surface water and eventually returns to high latitudes near the surface. The whole process may take a thousand years or more. In the Atlantic one of the important sources of this cold deep water seems to be in the Norwegian Sea. It appears that, perhaps intermittently, cold deep water from that sea flows into the Atlantic over the ridge between Greenland and Iceland. The nature of this flow is of the greatest importance to physical oceanography, and has an impact on such diverse subjects as the oxygen content of deep Atlantic waters and the capacity of the ocean to absorb excess carbon dioxide from the air. The Bedford Institute is in a particularly suitable position to study this phenomenon, both because of its location and because it possesses superb large research vessels which permit investigations to take place under the very severe conditions which can occur in these waters.

Canadian scientists are also in a very advantageous position to examine the mixing processes. This strong position results not from a specially favoured geography, but from the fact that the DRB Defence Research Establishment Pacific, for other reasons, has developed a superb technological capability for studying mixing–a capability unmatched elsewhere in the world. Not only does mixing determine the nature of the thermohaline circulation, but it is the mechanism by which surface waters are refertilized. Nutrients are depleted from the upper waters as organisms die and sink, but are returned to these upper waters. Mixing events, both in time and space, thus have profound ecological significance.

3. The sub-Arctic front in the Northeast Pacific. North Pacific waters may be crudely divided into a southern and northern region by a "front" designated by Tully as the Pacific sub-Arctic front. North of this front, the surface waters are much cooler and less saline than they are south of it. The ecologies of the two water masses are quite different. The northern region is dominated by the various species of Pacific salmon, while the southern waters feature the Pacific albacore. There is very little overlap, but the location of the front varies significantly from year to year. This variation seems to affect the migration routes of the Pacific salmon. The distribution of these surface water masses also appears to have very important effects on the climate of the whole northern hemisphere.

Strategically located in this area is the Canadian weather ship occupying "Station Papa". From this weather ship, scientists of FRB's Pacific Oceanographic Group have obtained the longest series of deep-sea oceanographic data extant. Theoreticians from all parts of the world make use of "Station Papa" data as their principal source of time series information. Canadians are therefore in a very strong position to undertake a systematic study of the time variation of this important section of the ocean. Such a study, and its impact upon climatological variations and upon the North Pacific fishery, is an obvious responsibility for the developing west coast oceanographic centre.

Air-Sea Interaction

As is evident from many of the topics treated in this report, we consider that to a large degree the ocean and the atmosphere should be regarded as a single system. The link between these two geophysical fluids is the air-sea interaction. Study of the air-sea interaction has developed strongly in Canada, particularly at the Universities of British Columbia and McGill and at the Bedford Institute. Although far more is known now than a decade ago, there is much yet to be learned. This work is of central importance to the Global Atmospheric Research Program, and should continue to constitute one of Canada's contributions to that great international enterprise. Increasingly it will call for the use of instrumented aircraft, and problems of interagency liaisons will arise. These problems are briefly treated in Chapter VI.

Air-sea interaction studies on the large scale–both in space and in time–are not as well developed in Canada as are those on a micro-meteorological scale. This is almost certainly a "coming" field and it is one of special importance to Canada. It is through studies of this kind that one might hope to predict the magnitude of the winter snow pack, or whether a prairie summer would be abnormally dry. For effectiveness, close collaboration is required between oceanographers and meteorologists. Such work is obviously suitable for universities.

A case can be made, however, for placing a small group of this kind in a government laboratory. There is much to be said for requiring a long-term forecast to be issued, even if to begin with the grounds upon which this forecast is based are tenuous at best and at worst are ill-founded. By asking for an actual forecast, one compels workers in the field to consider the effects of all phenomena of which they are aware and to attempt to be quantitative about their estimates. This is the principle upon which the United States Weather Bureau's 30-day forecast is issued. As a predictor it is virtually valueless, but it is important in revealing what kind of information must be gained so that meaningful forecasts can eventually be achieved. We do not recommend a massive attack on this problem, but rather that a group of three of four people be set up who would have ready access to a good computer. The group must be prevented from retiring into an ivory tower where they would look, not upon the real world, but only upon computer outputs. They must have constant access both to practising meteorologists and observational physical oceanographers.

Since the direct climatological effect of the Pacific is much greater than that of any other ocean on Canada, we suggest that this group operate from the developing west coast DEMAR laboratory. We also suggest that generation of expertise in this area be a duty of the University of British Columbia.

Anti-pollution Studies

In the previous section we looked at the complex ocean-atmosphere-ecology system. As we are beginning to learn, when man injects things into it–pollutes it–a whole intertwined web of adjustments begins. Sometimes readjustments are simple and local. More often, they seem to set in train complicated non-linear changes which radiate and may become amplified in unexpected ways. "Common sense" is often not very helpful.

In sea water, *sewage*–a rather obvious pollutant–has probably attracted far more concern than its importance deserves. Its principal damage is aesthetic. This aesthetic aspect is of very great importance and is rightly attracting attention. But it is important not to confuse it with danger to health, which generally seems minimal.

A solution to the aesthetic problem can be found in mechanical fragmentation, since sterilization requires much more expensive chemical treatment. By confusing the issues we may be making the situation much more difficult than is necessary. For example, there seems to be no reason at all why vessels should not be permitted to discharge fragmented sewage into coastal waters, provided it is not done too close to shore. The same can be said for smaller coastal communities–although there, of course, the "not too close to shore" part is of more concern. As a country, Canada is unusual in that, of its major conurbations, only Vancouver is sited on salt water. Thus, perhaps with this one exception, its problems do not arise from massive injections of treated sewage, whose chief adverse influence is in the contribution to eutrophication, but from the large number of comparatively small flows of untreated, or insufficiently treated, waste which can arise not only from coastal communities, but from resort areas and from shipping of all types. As has been indicated, it is easy to overstate the dangers from such waste.

As for *eutrophication*–it is less of a problem in sea water than it is in fresh water, both because of the flushing action of tides and because of the large quantity of nutrients already present to which the ecology is adapted. Nevertheless, the recent fate of Oslo Fjord shows us that this problem cannot be ignored in marine situations. Except for the region around Vancouver, and possibly the Victoria and the Halifax-Dartmouth area, there is no immediate need for concern. A careful watch should be kept in the above-named areas. If necessary the kind of ameliorative action which is now contemplated for inland waters must be taken.

The recent series of major *oil pollution* disasters–*Torrey Canyon*, Santa Barbara and *Arrow*–have attracted great and well-deserved concern. We believe that it must be recognized that there is no way, short of forbidding the transit and use of oil on and near the sea, of totally preventing disasters of this kind. *Time*[1] points out that 94 tankers have foundered in the last five years, and that two collisions occur every week.

[1]Time, December 26, 1969.

Since we cannot prevent them, it is necessary to be prepared to alleviate them. The increasing size of tankers, now up to 350 000 tons, and the possibility of large oil-carrying submarines, means that we must be prepared to cope with enormous quantities of spilled oil on an emergency basis.

It is painfully evident from Canadian experience in the case of the *Arrow* disaster that we do not yet know how to deal with oil spills on this scale, particularly in cold water. And the *Arrow* was a small ship by modern standards! We have known for several years that such disasters were going to occur. But there is no evidence that we are prepared to meet them. In an emergency, a series of *ad hoc* "make-do" measures by teams put together from everywhere at the last minute are clearly inadequate. A forthright mission-oriented program to assemble an expert team ready to go into immediate action with tested methods is needed *now*.

Disastrous events of this kind, hopefully, will be rare and widely scattered in Canadian waters. It is unreasonable to expect to maintain, in all the places where such disasters might occur, personnel whose sole duty it is to cope with such catastrophes. What is needed is something more analogous to a small town's volunteer fire brigade than to a large city's fire department. Most of the personnel required should have other duties. But we should not again be caught attempting untested solutions to a problem when it arises. Our "volunteer fire brigade" must be trained. Proper procedures for dealing with various kinds of oil spills should be worked out in advance, and the required people trained in advance. The requisite equipment should be kept in store, and adequately maintained. Transportation facilities must be made available so that equipment and personnel can be brought quickly to the site of the oil spill. In particular, techniques for dealing with oil spills in the Arctic must be found very soon.

The nature of the "volunteer fire brigade" is such that there would seem to be many advantages in turning over at least some of this responsibility to the Armed Forces. It is, after all, a major part of their function to become prepared for emergencies which everyone hopes will not happen. Such a responsibility should thus fit well into their ways of thinking and their other duties. Response will usually call for very rapid mobilization of effort, followed by air transport of substantial pieces of equipment to areas which may be remote from the population centres of the country. This characteristic also brings such a function closely into line with their other responsibilities. It is also worth noting that competence in dealing with oil spills would provide a foreign aid capability which might prove extraordinarily valuable.

Despite the spectacular nature of large oil spills, it has been pointed out[1] that more oil passes into the ocean every year from such routine operations as bilge pumping and the cleaning of fuel tanks than from marine disasters. The practice of dumping oil, for oily water, at sea is increasingly being recognized as unacceptable, particularly when carried out close to shore. Despite numerous regulations, damage is still done from time to time by careless or willful ship operators. There is no question that bilges have to be pumped, and that fuel tanks have to be cleaned. The only question is how and where. Canada could take the lead in providing the port facilities and enforcing the associated regulations needed to prevent these activities from taking place at sea. To devise techniques of disposing of this material without polluting the ocean is surely not beyond our ingenuity and should be made the responsibility of one of our research or development institutions. If we can find reasonable solutions to these problems, regulations requiring their use will undoubtedly be adopted in most countries around the world–and there will be more than a Canadian market for the kind of facilities.

In this as in other things, it is necessary to maintain a sense of proportion. A recent

[1]Wall Street Journal, November 26, 1969.

syndicated newspaper article makes the following statement: "A disaster 100 miles out at sea, involving a supertanker bound from say, Venezuela to Britain, could destroy a major part of Newfoundland's fishing grounds within days."[1]

If this statement were true, it would be necessary for us immediately to forbid the transit of large tankers through this area and to take forceful measures to enforce our prohibition. And these are the waters which those following in the wake of the *Manhattan* will ply!

Fortunately, the statement is not true. Oil from such a disaster might spread over an area 50 miles square to a thickness of $\frac{1}{500}$ inch or so. (This works out to about 300 000 tons.) This would be an awful mess, since an oil slick on water that "shows colour" is less than $\frac{1}{10}$ as thick. A lot of sea birds would die. Some beaches might be affected. But–the oil would disappear from the sea surface in a couple of weeks and all the evidence we have indicates that the fishery would not be affected at all.

With respect to *industrial pollution*, we believe that the federal government's responsibility for the marine environment gives it the opportunity to provide an example of the formulation of regulations which would be fair and workable and of enforcement which would be firm and equitable. We suggest the following principles, which go somewhat beyond those implicit in the proposed Canada Water Act.

1. It is the responsibility of industry to specify the nature of its proposed effluent when submitting an application for a licence to build and operate a plant.

2. For any industrial operation producing effluent which passes into the sea, an appropriate federal government agency, usually the Fisheries Research Board, should assign "approved effluent". The "approved effluent" should be specified in complete chemical detail and in the rate and scheduling of flow.

3. The federal government should take responsibility that the danger of damage from this "approved effluent" lies within acceptably small limits. (In many cases full scientific assurance will not be possible, but the best information available at the time should be used and an "engineering" decision made.)

4. It is industry's responsibility to monitor its effluent and to ensure quality control according to agreed specifications in accordance with good quality control principles. The government must have full access to any plant producing effluent in order to conduct such special checks as it deems necessary to ensure that the effluent is within the permissible range.

5. The operators of the plant should have no responsibility for any damage caused by "approved effluent". If the government agency has miscalculated in approving effluent and damage does arise, the government should be responsible. (There will be mishaps due to unforeseen ecological interactions.) Of course if later information indicates that the grounds upon which a certain effluent was declared acceptable were ill-founded, then it must be possible for government unilaterally to redefine the nature of the "approved effluent" and plants will have to take appropriate measures for the common good.

6. Fines should be established for any excess of effluent beyond the "approved" level–either of composition, flow rate, or departure from agreed schedules. These fines should increase rapidly with repeated offenses so that they do not constitute mere "licences to pollute". Fines should be assessed whether or not it is demonstrated that any damage has resulted. Companies should have privileges of presenting evidence from scientific studies and of requesting changes in approved levels where these appear unduly restrictive.

7. The company operating the plant should have unlimited liability for any damage resulting from effluent not within the "approved" limits.

It should not be the responsibility of the government to have to look through

[1] It would be invidious for us to identify the author, as his comment is no worse than many others. The name is available on request.

the operations of the plant to locate possible sources of undesirable pollution. This should be the responsibility of the plant. The government should, however, have full details of the operations within the plant, so that it may know what possible kinds of pollutants should be tested for. On the other hand, it should not be the responsibility of the plant operators to conduct ecological studies of the effects of industrial effluents upon the environment. Such a responsibility is too "open-ended". It is not possible to anticipate and examine *all* conceivable ecological effects. It should be a continuing government responsibility to consider the effects of various pollutants upon different ecological systems. Problems of this kind are particularly suitable for university researchers, and a large portion of the government's responsibility might be met by giving appropriate research grants to university research teams.

Also suitable for university research is the intense study needed to identify effects produced by *biochemical pollutants*, particularly those which are cumulative and are concentrated in the food chain. In particular, far more attention must be paid to the potential damage caused by long exposure to sublethal doses of a variety of chemicals. In this connection, more interest than has yet been aroused should be given to the automobile industry's new abilities to do without lead additives in gasoline. As has been pointed out, this additive has resulted in an enormous increase in the lead concentrations in the upper ocean– with unknown but perhaps not unimportant effects.

The problems arising from attempting to deal with pollution are manifold and varied, and we can attempt to point out only a few additional particularly important aspects.

Many kinds of pollution have been with us for so long that, despite the recent high intensity of public interest, they have not attracted much attention. One of these is the pollution of water by drifting wood. This problem is particularly severe on the west coast, where it has been familiar for so long that it is almost treated as part of the natural order of things. In the waters of the Strait of Georgia, logs, sometimes two feet or more in diameter and forty feet in length, present a real hazard to small craft and a not inconsiderable nuisance to larger ships. "Dead-heads" (logs in the last stages before becoming waterlogged and sinking) effectively prevent the use of hydrofoil craft in the Strait. Such craft are widely used in similar bodies of water in other parts of the world and might otherwise be very economical. Canada has, at considerable expense, gained an advanced technology in high-speed hydrofoils; it is unfortunate that this technology cannot be used in one of the places where it might most advantageously be applied.

Many of the logs find their way eventually onto beaches. In limited quantities drift wood on beaches may be considered an attraction; but the quantity on some Canadian beaches could hardly be considered limited, and is certainly no attraction. On bathing beaches these logs have to be disposed of. The traditional method is stacking and burning, but that raises problems of *air* pollution. All this indicates that some research should be carried out into techniques for recovering floating wood efficiently. A well-designed program might be largely self-supporting since the floating wood is far from valueless, particularly if it has not been left too long in the water. This area of research might well be undertaken by the British Columbia Research Council.

One must take a somewhat subtle view of the pollution problem. The attitude that we must not dispose of anything in the ocean is just as unwarranted as the attitude that the ocean is too large to be affected by anything that we are able to do. Thus, for example, there is no special reason why the wrecked automobile bodies which mar our landscape could not be disposed of in some places in the ocean without doing harm. (They might even do some good! Artificial reefs could be made of them which would serve fish or lobster populations.) The ability of the ocean to cleanse itself of pollution by sewage is very great indeed. All we need to do is ensure that dilution is sufficient so that we do not overtax this ability in small areas. Many kinds of inorganic material can be added without producing any effects at all, again provided that the dilution is sufficient. On the other hand, as has been pointed out, there are other things which are dangerous even in minute concentrations. Such things must be identified, and kept out of the sea.

In a May 1969 Report[1] of the Secretary General of the United Nations, we find the following warning:

"76. A very considerable amount of national legislation exists in many countries on certain aspects of the environment. In most cases, however, this legislation has accumulated throughout the history of the country and is not adapted to present conditions. It is fragmented, neglecting interactions, between environmental factors and is not accompanied by governmental financial assistance which could make it effective. Obsolete legal patterns, including obsolete land and water rights, hinder rational development and conservation of resources in many areas. Regulation in the environment field is generally considered as an unjustified restriction of human enterprise and is not understood as an integral part of long term and sustained development of resources."

Canadian legislation should be examined carefully to see whether this criticism is justified in our case.

The same document also points out:

"48. Although the International Convention for the prevention of pollution of the sea by oil has been in existence since 1954, oil pollution remains a major concern, and other forms of equally damaging pollution continue with little or no control."

[1]Problems of the human environment. E/4667, 26 May, 1969.

Canada could well take a lead in formulating further international conventions in this area.

Over Canadian objections, the "Conférence juridique internationale sur les dommages dus à la pollution des eaux de mer"[2] recently agreed to recommend to governments the restriction to $14 million of the liability of companies operating oil carriers for damages resulting from a major oil spill. Such a sum is unlikely to cover the costs of rectifying a major spill in the Arctic. It may be necessary for Canada to take advantage of its rights of control of movement in such waters to impose a greater responsibility on the operators of tankers using them.

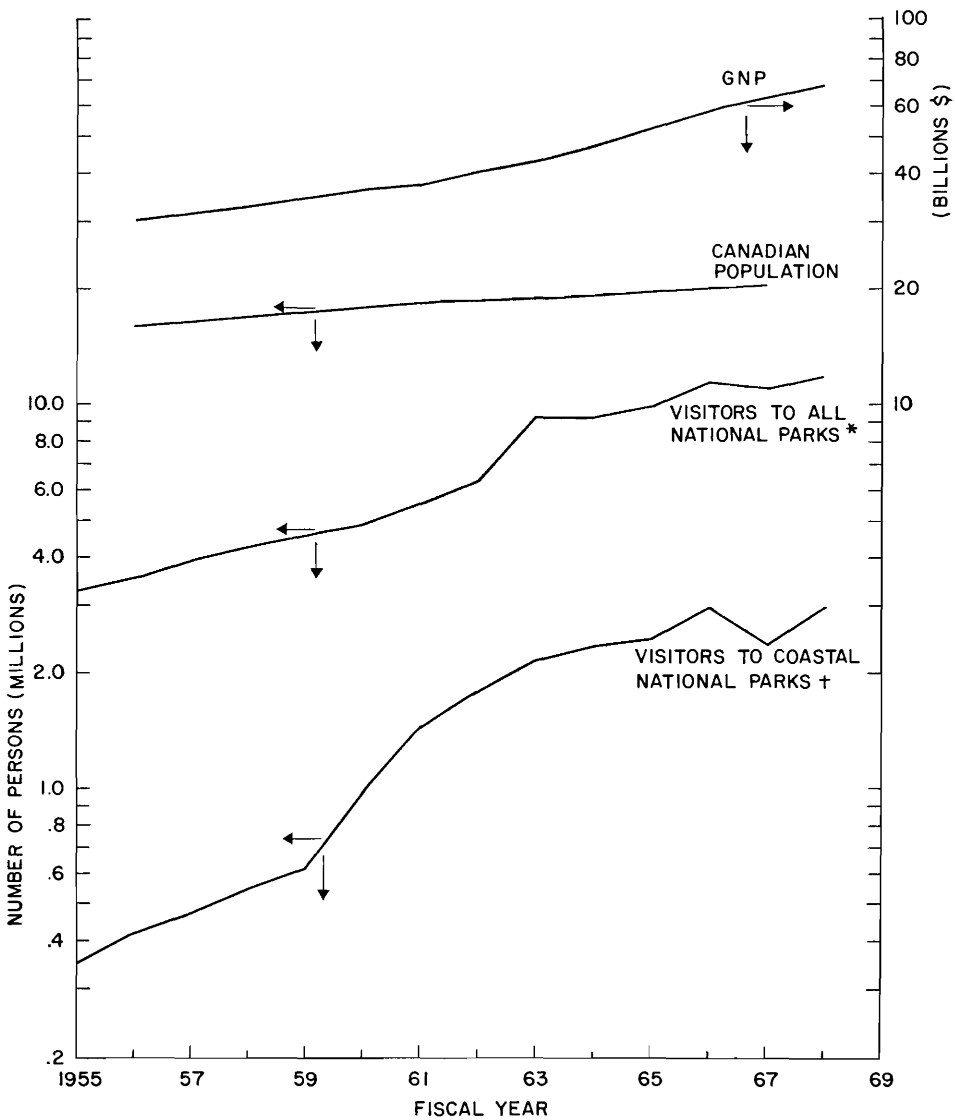
Recreation

Of the uses, as opposed to abuses, of the environment, none is more important than recreation. Regarded as an industry, no other has better prospects for sustained growth. Figure IV.2 shows that the growth rate of visitors to National Parks greatly exceeds population growth, and approaches that of the Gross National Product. Since expenditures per individual are also rising, the value of the industry is increasing even more rapidly.

A systems approach is needed to ensure an orderly development of balanced tourist services, to prevent rape of the coastal environment and to minimize social dislocation of the indigenous people. Such an approach will also make possible the development of an industry which will accommodate a diversity of human interests: fishing, boating, sailing, swimming, skin diving, underwater nature parks, aquaria, oceanographic museums. Such facilities can also be associated with land attractions like the reconstructed Louisburg Fortress. Much could be

[2]This conference was sponsored by the Intergovernmental Maritime Consultative Organization (IMCO).

Figure IV.2-Visitors to National Parks



*Eighteen national parks in 1968. Seventeen parks prior to 1968, and sixteen prior to 1960.
†Three coastal parks prior to 1960; four parks after 1960–all on the east coast.

done to improve the quality of tourist facilities, particularly in the Atlantic Provinces, if a scheme were devised whereby local operators could gain some experience of well-run facilities in other parts of the world.

It appears to us that some new administrative structures are needed, since at present there appears to be a lack of leadership and there is no clear administrative authority which considers tourism as part of the total economic system. For example, the relationship between the sports fishery and commercial fishery seems not to have received sufficient attention, and existing arrangements do not seem well designed to maximize the overall return to the economy.

The short tourist season of the Atlantic Provinces tends to militate against the economic viability of tourist facilities requiring large capital expenditures. Thus, for example, camping areas and trailer parks are more indicated for accommodation than motels and hotels. This situation in turn tends to reduce the economic impact of the industry. Further, a recent study[1] indicates that the economic multiplier for tourism in the Atlantic Provinces is only 1.6 as opposed to over 2.1 for most other provinces and 2.8 for Canada as a whole. Daneau[2] estimates an even lower figure of between 1.2 and 1.5 on the basis of a study in the Gaspé of Quebec. The true economic value of some low-charge tourist facilities may therefore be doubtful. For Canada to make facilities available to Canadians seeking low-cost holidays is obviously socially desirable. However it is more questionable if there is any advantage to Canada in having such facilities widely used by non-Canadians. In fact, since the presence of large numbers of people tends to reduce the attractiveness of a tourist area, the effect of making low-cost facilities freely available to non-Canadians may be entirely disadvantageous. It would seem that a careful cost-benefit study should be made–including social costs–and if need be, some device sought by which such tourists would pay not only the direct costs of providing them with services, but also some fee for the reduction in amenities which their very presence causes.

These considerations apply not only to those taking camping holidays. On the west coast large numbers of U.S. boats can now be found in Canadian waters, using Canadian facilities, and putting little or nothing into the Canadian economy. Since one of the attractions of these waters is the low population density surrounding them, the impact of large numbers of boats on the amenity is very appreciable, particularly in the few anchoring areas available in these generally deep waters. In certain areas they create extra costs by being hazards to navigation and requiring rescue operations. Again some way should be found by which these visitors pay not only for the use of facilities provided, but a fee which reflects the social cost of permitting them to be present. There has never been any hesitation in charging much larger hunting licence fees to non-residents than to residents or in requiring professional guide services. There would seem good reason why a similar principle should be adapted to other forms of recreation, including requiring pilotage or guide services in certain situations.

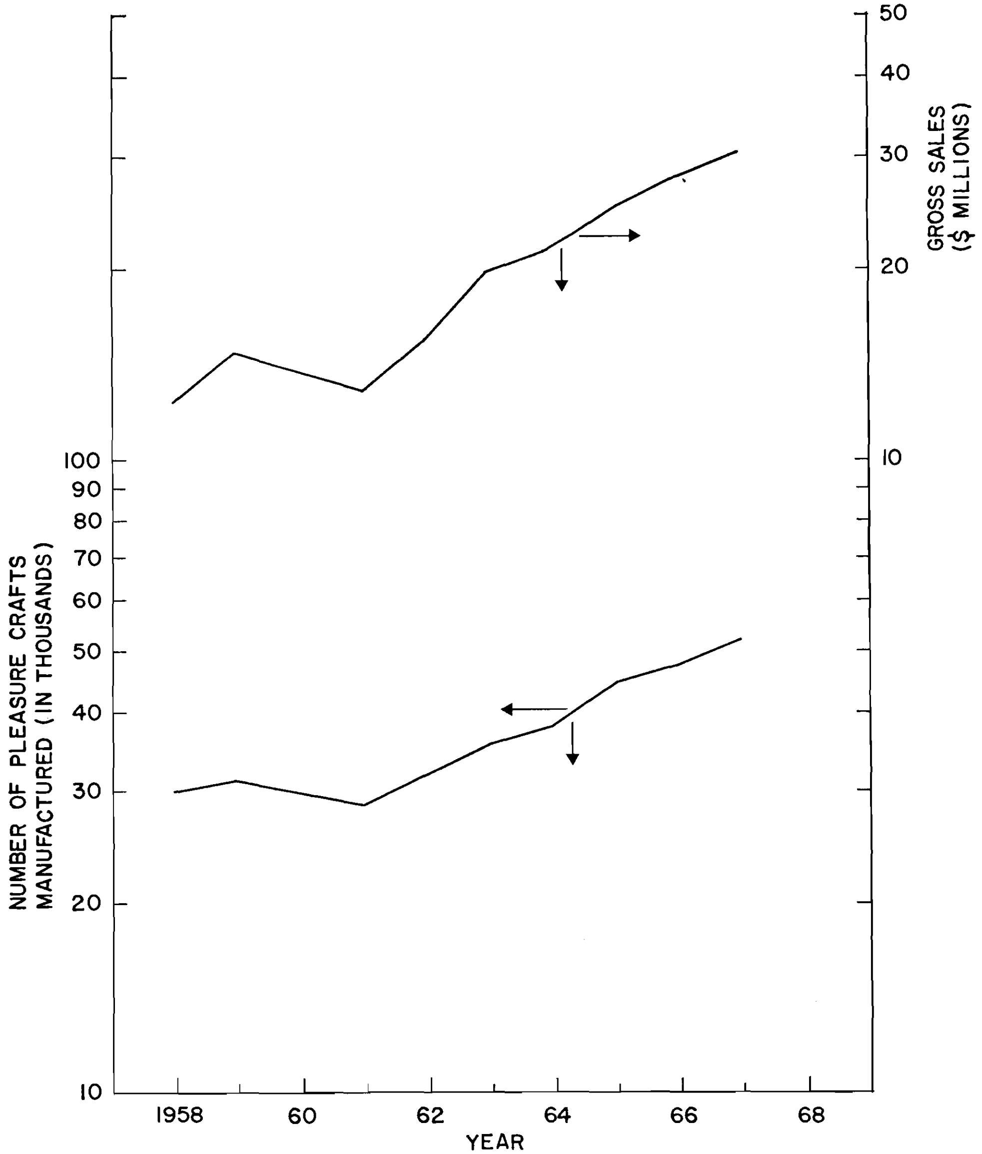
A rapidly developing industry associated with recreation is the design and production of pleasure craft of various kinds. The growth of this industry and its potential are indicated in Figure IV.3 which shows the growth in sales and numbers of pleasure craft in Canada over the last few years. Similar growth can be seen in other parts of the world and there are important export possibilities, some of which are already being realized.

The market is highly competitive and new designs are constantly being introduced. The Canadian industry would be in a stronger position if more test facilities were provided for it. The National Research Council has such facilities, and is

[1]By Kates, Peat, Marwick & Co. reported in the Globe and Mail, Oct. 9, 1969.

[2]Daneau, M., background study prepared for this report.

Figure IV.3-Growth of the Pleasure Craft Industry



developing more in its Ottawa establishment. This location is entirely suitable for large vessels, for expensive racing yachts, and for craft designed and built in the central provinces. For the construction of smaller craft on the two coasts, however, the Ottawa location makes them rather inaccessible. It would be avisable to set up limited testing facilities on each of the coasts. This question will be returned to in Chapter VI.

Marine sciences and technology must also contribute to recreation by providing design and safety criteria for pleasure craft and shore facilities, increased reliability of forecasts of winds, currents, sea states and climate, and provision of charts for boating and fishing.

Down to the Sea in Ships

Ice in Navigable Waters

Of Canada's enormous coastline only the west coast and the southern shores of New Brunswick and Nova Scotia are free from ice. To a considerable extent the story of the development of marine transport in Canadian waters has been the story of learning how to deal with ice. The present federal government organization entrusted with the task of co-ordinating and encouraging work on this problem defies *a priori* logic but in fact seems to work very well. It consists of the Working Group on Ice in Navigable Waters. This working group was set up in 1957 by the Joint Committee on Oceanography and now reports to the Canadian Committee on Oceanography, itself a body whose existence has not been acknowledged by any legislation. The working group consists of members from a number of federal government departments and from the Universities of Toronto and McGill. Its recommendations have led to action on such diverse activities as satellite studies of ice, the use of under-ice bubbler systems, studies of methods of keeping seaway locks ice free, and translations of papers from Russian and Japanese.

In recent years the most dramatic results of learning how to deal with ice have been achieved in the Gulf of St. Lawrence. The increase in the availability of icebreaker service and the introduction of an ice-reporting forecast service have been very influential in the dramatic increase of winter shipping in the Gulf. Confidence which these services gives is reflected in sharply reduced insurance rates. According to the brief submitted by the Working Group on Ice in Navigable Waters to this study, in 1968 there were 688 winter passages through Cabot Strait, compared with 10 in 1954. Winter tonnage was around 25 million in 1968, compared with slightly over 9 million tons in 1963. It is estimated in the brief that the increase in winter shipping has yielded an increase in economic activity around the Gulf of St. Lawrence of a least half a billion dollars per year.

There is still more to be done in the Gulf, and a concentrated attack on this problem is discussed in Chapter V. Now, however, the problems of navigation in the Arctic demand our attention. The dramatic voyage of the *Manhattan* has demonstrated that there are possibilities of year-round, or nearly year-round, shipping in this area. It is important to recognize that oil is not the only cargo which can be moved economically in large bulk carriers. For Canada in the long run it may not be the most important one. While the northern and westerly parts of the Arctic region seem very promising for oil, the southeasterly portion and the areas around Hudson Bay give promise of ore bodies similar to those found in other parts of the Canadian Shield. Some such ore bodies have already been located around Baffin and Hudson Bays. It is probable that the potential has hardly been scratched.

To exploit these resources will require either the establishment of substantial industrial activity in these inhospitable regions or the movement of ore in bulk to more southern regions. The siting of plants for producing concentrates and even refined metals in the Arctic is increasingly being recognized as practicable. Nevertheless, past experience indicates that the movement of unrefined ore will be an important aspect of Canadian development of Arctic resources. No existing technique of bulk transport competes with movement by sea. While the movement of solids by specially adapted pipelines or by enormous conveyor belts has been mooted, it remains probable that sea transport will be a favoured method, provided that it is feasible. The same may also be true for transporting oil, despite the fact that oil transport by pipeline is a proven technique.

We therefore endorse the conclusions reached by the Working Group on Ice in Navigable Waters, which suggests three interrelated areas of study:

1. Studies of methods whereby those coasts of Canada which are heavily ice-infested can be opened up for shipping for the longest possible time, and of methods to make shipping from ports on these coasts competitive in world trade.
2. Climatic and environmental studies which will assist in the prediction of the growth, generation and movement of ice.
3. Studies of the effects of ice on structures. Here particular attention should be paid to port installation and to ships.

The design and construction of year-round port facilities in regions subject to very cold temperatures is a need which we share with few other nations, and which deserves particular Canadian attention.

At the present moment, there does not seem to be need for a huge "crash" program to overcome these problems. Nevertheless, an immediate start should be made in order to identify and find solutions for the technological problems, so that an expensive emergency operation will not be required when the need does become even more urgent. The urgency is such that an engineering approach is required. While scientific studies of such things as the rheology of sea ice are important, and are logical areas for university research, we cannot wait for them to come to full fruition. The scientific base is already sufficient that many of the technological problems can be dealt with semi-empirically.

Considerable effort should be made to exchange information with those few countries–especially the Soviet Union–also faced with these severe problems. One detail of the present structure of the Working Group on Ice in Navigable Waters may, in this context, be somewhat unfortunate. It operates from the Defence Research Establishment Ottawa, for no better reason than that some of its most energetic and dedicated members work at that Establishment. It is possible to argue that there could be no better reasons for choosing a site–but the fact that its chairman and secretary are in a Defence Establishment, and that communications from the working group frequently come out under a DRB letterhead, must at least somewhat inhibit information exchanges with the Soviet Union, which is a world leader in this field. Such exchanges are clearly desirable and it would seem advisable to alter the structure somewhat so that the working group could operate from a non-defence base.

Canadian Merchant Marine

As was stated in Chapter I, we shall deal only with certain selected areas of the large problem of the Canadian Merchant Marine.

On both east and west coasts there are large bodies of water, important to transportation, with characteristics unlike that of the deep ocean. Special vessels designed specifically for these waters may have marked competitive advantages. Also, on the west coast in particular, a very high level of expertise in towing has been developed. This expertise may well be exploitable more widely. Again, there are special Canadian problems concerning ice, which should lead to special Canadian answers.

Quite apart from these considerations, a case can be made for the creation and maintenance of some Canadian deep-sea

Merchant Marine. This case lies principally in the use of such a fleet as demonstration vessels for auxiliary gear of high technological content which can be developed and produced in Canada. For example, Canadian ports are among the world's leaders in handling material in bulk–wheat, iron ore, coal, potash, etc. It is to Canadian advantage that the techniques of handling such materials be brought to a high level of efficiency. The ingenuity of Canadians should be challenged not only to provide dock facilities, but also to provide matching facilities on ships. Such developments would be far more efficacious if there were Canadian ships to work with.

A considerable amount can be done with the Lake and Gulf of St. Lawrence carriers already under Canadian Flag. However, there are certain problems, both of size and of sea-keeping characteristics, which large modern seagoing bulk carriers have in contrast to lake carriers. Serious thought should be given to the acquisition, or construction, of a few such large bulk carriers, the principal use of which would be to demonstrate sophisticated techniques of ship operation, and of loading and unloading. The same arguments can be applied to container carriers, where there may be even more scope for ingenuity.

It is a curious fact that in Canada, while there is a well-organized subsidy program for ships, there has been little or no comparable encouragement for ship's equipment. It appears to us important that much more emphasis should be put on this aspect of marine engineering. The two industries are of comparable magnitude, and there is at least as much room for imagination and inventiveness in the design of equipment as in the design of ships. Further, the opportunities of exporting equipment probably considerably exceed that of ship's hulls. It should be some ironic satisfaction to Canadians that, in the trial runs of research vessels, the faults found are rarely concerned with structural problems or other features under direct control of our shipyards, but are problems with the foreign-built engines and equipment, or with faults in design.

The shore facilities associated with marine transport also demand considerable attention. Increasingly, both in Canada and abroad, ports are treated as single entities and are designed with an overall plan. In Canada all major ports are under the control of the National Harbours Board, and port design is carried out "in-house" by this organization. This arrangement is a historical one and has some advantages. It also has some disadvantages. New port facilities are required all over the world, including many in places which have not reached a stage of development such as to permit them to undertake their own designs. There are certain large Canadian concerns which have submitted bids for the design and construction of ports in various parts of the world. We may expect such activity to increase. The bids of Canadian companies would be appreciably more likely to be accepted if they could demonstrate their competence. It appears to us that the National Harbours Board would be well advised to contract out a great deal of the design and construction of new harbour facilities. Alternatively, or additionally, the National Harbours Board should be prepared to have its experts used as consultants to Canadian firms bidding on the design and construction of harbour facilities abroad.[1]

It is our opinion that the advantages of having Canadian construction firms building such large engineering works abroad cannot be overestimated. Every such venture is likely to generate a great deal of new business of many kinds. Large amounts of the equipment, both new and replacement, would be Canadian. Further, the attitude that Canada was a reasonable place to look for such equipment would help in sales throughout that country.

[1]This is a particular example of a more general policy which we would like to see adopted. The concept is developed in Chapter VI.

Minerals from the Sea

Although such authors as Mero[1] are extremely enthusiastic and optimistic about the prospects of looking to the sea for minerals, we are inclined to adopt the more conservative view expressed by Cloud[2] who says:

" 'The mineral cornucopia' beneath the sea thus exists only in hyperbole. What is actually won from it will be the result of persistent, imaginative research, inspired invention, bold and skillful experiment, and intelligent application and management–and resources found will come mostly from submerged continental shelves, slopes, and rises. Whether they will be large or small is not known. It is a fair guess that they will be respectably large; but if present conceptions of earth's structure and seafloor composition and history are even approximately correct, minerals from the sea bed are not likely to compare in volume or value with those yet to be taken from the emerged land."

In the course of our study, it became clear to us that the Canadian mining industry feels itself under no pressure or obligation to look to the offshore region for mineral developments. On the other hand, there seems to be great confidence that if a mineral resource were to be discovered offshore, the industry would find some way of getting it out. The general reaction seems to be that if the Canadian government wished to encourage offshore developments, the best way would be through special depletion allowances and other tax relief.

It is our opinion that at the present time no such special incentives are warranted. For the next decade the challenges of dealing with offshore oil exploration and exploitation will probably tax our abilities to develop a Canadian competence in marine technology to the limit. When the time does come for offshore mineral recovery, the experience gained in working with offshore oil should be relevant and applicable.

One type of submerged mineral resource may be of much more immediate importance: placer deposits on submerged beaches. There is already some activity of this kind off the coast of Nova Scotia and it may become of local importance in other places. Certainly the possibilities of such deposits should not be ignored when surveys are conducted on the shelves.

Whenever resources are located, the question of exploitation will of course arise. Usually, novel techniques will be required, and an examination of needs for mineral recovery should be part of the function of the Development Corporation which is discussed in Chapter VI.

Although at present the problems of working offshore seem formidable, there are also certain advantages. Since one should be able to load bulk carriers directly at the site of the mine, the transportation problem may be much simpler than in many terrestrial areas. The notion of offshore mining should therefore not be put aside. Geological and geophysical work conducted by government agencies should certainly include studies of the kind which might lead to the location of ore bodies. There are probably some fundamental engineering problems particularly suitable for government-supported university research, and which could be undertaken without delay.

In recent years much publicity has been given to the possibility of recovering a variety of minerals from the "manganese nodules" which pave large areas of the sea floor. There are even some tentative ventures by United States interests to recover some of this material in commercial quantities. Canada would not seem to be especially favourably sited for a concentration on this problem. Although the evidence is still rather thin, what there is seems to indicate that the major concentrations of manganese nodules occur at latitudes somewhat lower

[1]Mero, J.L. Mineral resources of the sea. New York, Elsevier, 1965.

[2]Cloud, Preston. Mineral resources from the sea. *In* Resources and man. San Francisco, W. H. Freeman and Co., 1969.

than those of Canadian waters. Further, we have no large "mid-depth" region comparable with the Blake Plateau off the U.S. southeastern seaboard, where extensive deposits occur in water less than half as deep as most of the ocean floor. Therefore, we do not believe that opportunities for exploiting manganese nodules should command any major Canadian effort in the immediate future. Nevertheless survey programs in waters adjacent to Canada should include an attempt to inventory the manganese nodule resource, and a close watch should be maintained for any possible technological breakthroughs on their recovery. Further, the metallurgical problems of dealing with the materials in manganese nodules are largely unsolved. These problems are eminently suitable for government-supported university research.

There remains the possibility of obtaining minerals directly from sea water–particularly magnesium. Canada might seem to have no special advantages in this regard, but it is worth recalling that our massive aluminum production industry is based solely on a plentiful supply of cheap energy. The one Canadian venture in magnesium extraction, that in Newfoundland, also depends upon low-cost power. The UNESCO document *Perspective in Oceanography, 1968* contends that magnesium has not had sufficient attention from metallurgists, and so is not used by industry to the extent that it might be. Since Canada's competitive position in producing magnesium would seem to be fully comparable in principle to its position in producing aluminum, a considerable metallurgical effort would seem to be warranted. If such an effort had the success of the one which has been undertaken to find uses for nickel, a major industry would result.

Defence

During and since the Second World War, the role of Canada's Maritime Forces has centred on anti-submarine warfare. With the advent of the missile-carrying nuclear boat, the submarine has become a more formidable weapon than ever. Anti-submarine activities thus continue to be of great importance. Canada's Maritime Forces will continue to need improved technological capability, more oceanographic information and, if possible oceanographic forecasting. It is unlikely that the percentage of the total defence expenditure devoted to Maritime Forces will change significantly, although the proportionate emphasis on defence relative to other aspects of marine science and technology will undoubtedly decline. Defence needs will continue to make demands upon the oceanographic community for information and upon the technological community for ingenuity. It should continue to be one of the principal objectives of oceanographic research to attempt to understand the seas sufficiently that useful predictions can be made about physical and biological oceanographic parameters. These predictions will be important to defence as well as to fisheries and to meteorology.

More than this we are unable to say, for many of the details of defence needs are necessarily shrouded by the requirements of security.

We wish to endorse the present policy of the Department of National Defence, by which oceanographic support for the Maritime Forces is *not* supplied entirely by Defence Research Board establishments. These establishments will have special expertise, for example in underwater acoustics. However, it is our opinion that they should continue to lean on the Department of Energy, Mines and Resources and the Fisheries Research Board laboratories for information and assistance in obtaining and analysing such things as temperature and salinity data, bottom samples and the distribution and classification of marine organisms. Indeed to the extent possible, all marine defence research activities should be co-ordinated with civilian marine activities to enhance the effectiveness of both. This opinion is another example of our general view, which will be developed in Chapter VI, that individual organizations should not attempt to become fully self-sufficient.

Hydrography

Canada has had a systematic program in marine hydrography which has resulted in a great improvement in the mapping of underwater topography surrounding our shores. However, there remains very much to be done. Emery[1] shows the Canadian continental shelf to be poorly or only fairly well-known in contrast to American and European areas. Our shorelines and shelves are so vast that no end is in sight for this work. Further, the increase in pleasure traffic and the demands of offshore oil exploration call for detailed mapping not previously anticipated. In addition, both wave climate information and the mapping of currents are much less complete than is desirable. One can thus anticipate a steady growth of hydrographic survey operations.

It is our opinion that virtually all of this growth should take place by systematically contracting out surveys. The government in-house surveying capability need not expand, and could eventually even contract slightly. The Department of Energy, Mines and Resources will have to continue to take responsibility for the reliability of charts produced and for determining priorities of areas and parameters to be charted. Increasingly, government duties should be concentrated on setting standards and ensuring quality control. More and more of the routine surveying should be let to contract with private operators. Contracts should not occupy the full capability of these operators, who would be expected to sell their services not only to the government but also to private concerns such as, for example, oil companies and private marine operators. Private survey vessels could also be available to be contracted as research vessels by other government agencies and by universities.

[1]Emery, K.O. The continental shelves. Scientific American, September 1969.

Estuarine Studies

Pleistocene glaciation has left the Canadian coastline as rugged and indented as any in the world. The variety of estuaries which have been left demand study for a number of reasons. Many of them contain important sports and commercial fisheries. On the shores of many of them are located industries–and others are probable sites for future industries. The flushing of an estuary is usually a very complex physical oceanographic problem, and a very important one. It governs the dispersal and dilution of pollutants introduced into the water, and also the way in which the deeper water is reoxygenated.

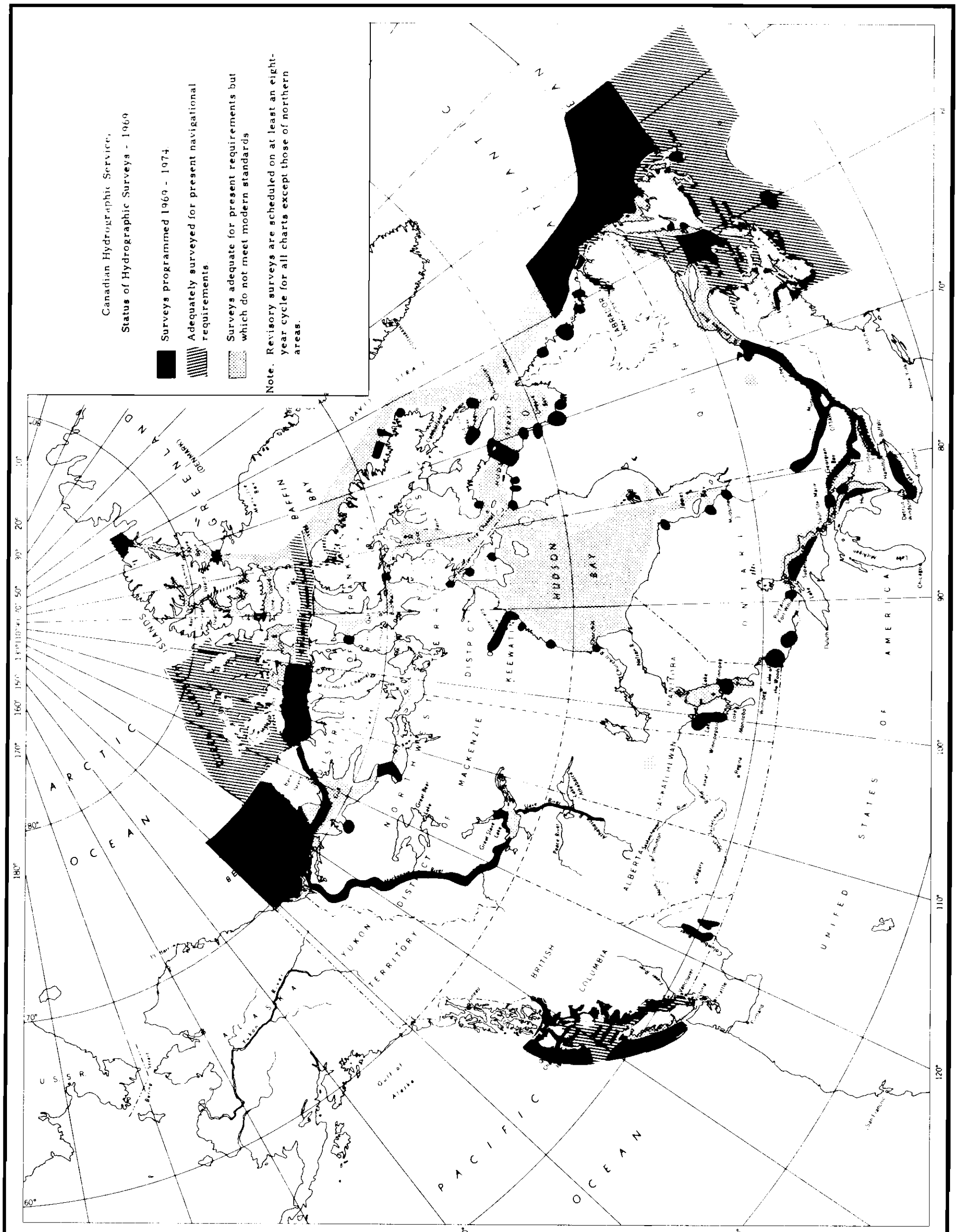
No less important is the fact that many deep-sea phenomena–both physical and biological–are modelled on smaller scale in some estuaries, particularly in the deep inlets. Studies made on this manageable scale can have relevance to much larger bodies of water.

After a vigorous start on the west coast in the late 1940s and 50s, estuarine studies have languished somewhat as the laboratories have turned their energies to other problems. It is probable that some return to concentration on these deep-type estuaries would be profitable, and it is recommended. Of course, both the Gulf of St. Lawrence and Strait of Georgia projects suggested in this document have a very strong estuarine component.

Geophysics

The efforts of the Bedford Institute and Dalhousie University have given Canada a marine geophysical capability on the east coast which is of high international repute. On the west coast the picture is not as favourable. Although there are some stirrings at the University of British Columbia and in the Department of Energy, Mines and Resources, no strong program has yet developed. One is needed. The region offshore from the Canadian west coast seems to be very unusual geophysically, and a combined land-sea program to study phenomena in and west

Figure IV.4-Status of Hydrographic Surveys, 1969 Canadian Hydrographic Service



of the Rocky Mountains is of considerable importance. Close liaison should be maintained between university and government work.

As was indicated earlier, marine geophysics is an essential part of the education of the geophysicist. One can therefore anticipate demands from inland universities for opportunities to participate in marine geophysical studies. These demands will best be met by working in close collaboration with the laboratories of the Department of Energy, Mines and Resources. Increased understanding of the nature of geological and geophysical processes cannot fail to increase the efficiency with which mineral–including oil–resources are located. This aspect is quite apart from the purely scientific motivation of trying to understand the nature of the earth we inhabit. In recent years marine geophysics has been a spearhead in this search for understanding.

Geophysics has another role to play. In connection with the work of the United Nations Seabed Committee on the development of a legal regime to govern the exploration and exploitation of seabed resources beyond the limits of national jurisdiction, Canada has taken the position that there must be international agreement on a precise definition for the outer limit of the continental shelf to replace the present "elastic" limit incorporated in the 1958 Geneva Convention on the Continental Shelf. The stated Canadian position is that the outer boundary of the continental shelf should be the submerged continental margin (i.e. shelf, slope and at least part of the rise). We support this position, but contend that this offshore boundary needs sharper definition than it has yet been given. It should be one of the important functions of government marine geophysics to survey the continental boundaries so that we may be in a strong position to draw our own line. As we see it, the boundary should be placed at the bottom of the continental rise so that the thick bottom sediments of this region lie within national jurisdiction. Unfortunately, however, the neat divisions which are found in textbooks are not as easily located in fact. A substantial geophysical program is thus required. Fortunately, the work will have multiple uses, and should be very relevant to the important question of whether there are petroleum resources in thick sediments in deep water.

Distant Cruises by Canadian Research Vessels

It has been pointed out that, among countries of comparably large oceanographic capability, Canada has spent proportionately less time and effort in ventures far from our shores. This has been largely a consequence of deliberate policy of the Canadian Committee on Oceanography, recognizing the immediate importance of the many problems nearer to hand. It must, nevertheless, be recognized that, despite the magnitude of the oceanographic tasks in waters adjacent to our shores, Canadian oceanographers will from time to time need to conduct studies much farther afield. The most important of these needs is the requirement to test the validity of certain concepts which have application to Canadian waters. Frequently the situation in Canadian waters may be so complex that clear-cut inferences about the truth of the concept cannot be drawn from observations there. There may be other regions on the earth, perhaps far from our shores, where much more clear-cut evidence may be obtained. Further, hypotheses may be formulated, based on observations of Canadian waters, which can only be tested by comparing them with different regions where some of the parameters vary.

It will frequently be the case that such needs can be met by having Canadian oceanographers and their equipment transported to other parts of the world to work on foreign research vessels. Funds must be made available to permit such activity. (And reciprocally, foreign research workers and their equipment should be permitted use of Canadian vessels from time to time.) There may, however, be occasions when only the sending of a Canadian research vessel will meet the need. If the scientific importance to Canada is great enough, there should be no reluctance to support such cruises.

It was pointed out in Chapter I, Section 9, that Canada has both a responsibility and a need to participate in international scientific ventures. Frequently this participation can be accomplished by activities in waters not too far from our shores. However, it must be accepted that from time to time there will be international studies of great concern to Canada, which can be participated in only by sending equipment and personnel to distant waters. The Global Atmospheric Research Program (GARP) Tropical Experiments, and studies of the oceanography and fisheries off Peru and off West Africa, are examples of situations where Canadian experts could contribute significantly, where Canadian science has an interest, and where Canada as a nation has some responsibility.

The question of the ability of states to conduct scientific work on the continental shelves–and even in the territorial waters–of foreign countries has been a subject of debate at the Geneva Conferences on the Law of the Sea. Our position has been, and should continue to be, that permission to conduct such research will be granted by Canada for areas under Canadian jurisdiction provided the results of the research are openly published, and that we reserve the right to have Canadian scientists participate in the work on the foreign research vessels while they are within the area of Canadian responsibility.

We should frequently, if not usually, take advantage of this right to join in the work on foreign research vessels. The very fact that other countries find it necessary to work in areas under Canadian jurisdiction is an indication that some of our research programs are incomplete–so there should certainly be something to be learned.

Reciprocally, of course, we must plan to have foreign workers aboard our ships. The contacts made will yield widespread advantages not only in the exchange of information and technique, but also in the general fostering of goodwill.

Marine Science and Technology as an Instrument of Foreign Policy

Marine science and technology has been and in future will be still more an element in and an instrument of the foreign policy of the major coastal states. This is so because both the traditional and the newer uses of the sea have an obvious international aspect and because they are assuming ever greater importance in a resource-hungry world. The sea represents a vast arena for the conduct of international relationships and attention is increasingly directed to this area in the search for new forms of international co-operation. In this game, states have all the advantages that come from playing with loaded dice if they possess a strong, solid base of marine science and technology.

If Canada is to protect its vital interests in the uses of the sea and is to have a real voice in the determination of international arrangements related to those uses, then Canada must clearly define its foreign policy objectives in relation to its national stake in the oceans and must marshall its scientific and technological capabilities in support of these objectives. Although the Department of External Affairs is not an operational agency in the field of oceanography, it has the responsibility for advising the government on the foreign policy which will best advance Canada's marine interests. In carrying out this task, the Department must identify, and pursue the negotiation of, international arrangements which will serve both Canadian interests and the needs of the international community. The Department will be severely handicapped in carrying out these responsibilities, however, without the advice and active collaboration of scientists and technologists engaged in a wide-ranging program of ocean research and development. Nowhere, perhaps, is this more true than in the immensely complex field of the law of the sea, which is undergoing a rapid and radical transformation as a result of scientific and technological progress. Science and technology have created new needs and new problems in the law of the sea, and science and technology will have an important part to play in the search for solutions to these needs and problems.

Thus Canada must develop an organizational framework which will establish the required close relationship between activities in the field of marine science and technology and Canada's national objectives and its corresponding foreign policy.

In addition to these considerations, there are some aspects of Canadian marine science and technology that may be carried out for reasons somewhat remote from the economic, environmental and scientific justification emphasized throughout this report. As a vehicle for expressing Canadian foreign policy, marine science and technology can also be useful in "showing the flag" and in the field of foreign aid.

Showing the Flag

Many of the topics discussed in this report, and several activities already carried out by Canadian marine scientists, contain at least a trace of flag-showing in their motivation. The place where we wish to have our flag flown highest and most visibly is in those regions where we wish to assert our sovereignty. This motivation is to be found in such existing projects as the Polar Continental Shelf. These scientific projects can, of course, be defended on other grounds as well. Beyond these areas one can find a trace of nationalistic flavouring in such other enterprises as *Hudson 70*, the 1968 cruise of *Endeavour* to Japan, and the 1963 appearance of *Oshawa* at the San Francisco IUGG meeting. In each case the overriding consideration was scientific. But the other aspect should be neither overlooked nor decried. The appearance of a well-equipped, efficiently operated Canadian research vessel, conducting an intelligently designed research program with sophisticated instruments–especially Canadian-built ones–of course enhances Canadian prestige. Nations–even nations such as Canada without foreign ambitions–have never taken their prestige lightly. Also, at times it may be plain good business; it is good advertising.

It is very difficult to decide who should determine how much of this activity is to be carried out and what is to be its nature. Certainly, marine scientists rarely like to see their time or their vessel's time used *merely* for prestige purposes, and the places where it may be desirable to show the flag may not coincide well with places where the scientific interest would easily be reconciled with cruises of this kind. We suggest that such cruises be rare: not more than one per year for the whole country, and determined at a high level. The Canadian Committee on Oceanography would seem to be a suitable vehicle for choosing appropriate ships and even for suggesting appropriate cruises.

Foreign Aid

As has been pointed out from place to place in this document, there are several aspects of marine science and technology that can be used as valuable portions of Canada's foreign aid program. These include the performing of surveys of various kinds in foreign waters, training of personnel from underdeveloped countries both in the universities and at research establishments, the design and construction of port facilities, emergency help in dealing with pollution problems, and many others. In the marine area, perhaps more than most, it is possible to provide aid which is uncoloured by any suspicion of interference in the internal affairs of the receiving country.

Chapter V

A Program for the 1970s

From the foregoing chapters it will be clear that the natural advantages of our geography present Canadians with startlingly large potential marine resources. There is no doubt that we could reap real benefits for ourselves and, if we choose, for others as well, by the orderly development of these resources. However, while such new development of our primary resources is quite clearly economically advantageous now in the case of oil, it is equally clear that maximum advantage will not accrue to Canadians without the expenditure of considerable effort on our part, combined with an exercise of control to ensure that this exploitation is used to help us in the achievement of our national cultural and economic goals.

In this report we have made an effort first of all to show that the new developments, in oil and gas exploitation in particular, are potentially so large that we must expect them to have a major impact on the social patterns of the country. Even very conservative estimates place the reserves and production rates off the east coast alone at a level higher than that of the Alberta oilfields. In addition, the western Arctic basin may well turn out to be the greatest oil reserve in the world. Some of the technology for getting this oil out of the continental shelves and to markets exists in certain parts of the world, chiefly in the hands of our southern neighbours. But it remains inadequate for the rigorous conditions to be found in Canada, particularly where there is heavy ice. There thus exists a need for major technological advances. These will be accompanied by the development of a secondary industry of large size and great complexity. Much of this development could be carried out by Canadians, and we believe that steps must be taken to ensure that it is. Two major projects to this end are discussed in Chapter II, and proposed systems for managing them are included in Chapter VI. We do not take this attitude simply because of the economic return, though this could be very large by our national standards. More importantly, this marine development gives a major new opportunity to use our very best technical, scientific and management skills in manufacturing and major construction, to say nothing of the many associated service activities. It thus offers a chance to expand significantly the range of occupational opportunities open to Canadians. The central aim of a marine program for the 1970s must surely not simply stress increased resource exploitation. The important objective for Canada must be the development of an independent Canadian technological capacity and secondary industry associated with this exploitation.

The oceans are a very special kind of environment for man. Our use and control of them have always been so tenuous that the legal and administrative mechanisms that guide our activities on land are not easily adapted to conditions there. It has always been recognized that no one can really assert ownership over marine fishes until they are caught. The small seaward extensions of national boundaries do not help much because most fish migrate across them, no matter what fishing boats do. Special and somewhat different considerations apply to the control of shipping, or to the rights to seabed exploitation. To these are now added our growing recognition of problems of pollution and the widespread influence of sea conditions on climate. Because of their special nature, and perhaps because in the total economic picture fisheries seemed relatively unimportant for some years after the Second World War, nations of the world used marine fisheries problems as instruments in international communication and negotiations, and as experiments in international cooperation.

Unfortunately, this situation has now changed with the realization that during the past decade increases in fisheries production have played a remarkably important role in the fact that food production has exceeded population growth.[1]

[1]Food production–shortage or surplus? Nature, 225: 9. January 3, 1970.

In addition, as our scientific information on fisheries has grown, so too have the possibilities for the effective assertion of either national jurisdiction or international control. The borderlines between unilateral (national) and multilateral (international) control in transportation and in sea-floor exploitation are similarly far from well established. The need for mechanisms for international pollution control and climatic manipulation are only beginning to be recognized, as are the possibilities for using marine knowledge as a component of foreign "self-aid" programs.

It is clear that in a Canadian marine program for the 1970s these marine activities will be effective instruments in the promulgation of both national and international policy and must therefore command special attention from the Canadian government.

We have emphasized that marine industrial developments associated with oil must inevitably change the face and character of the affected regions of Canada. Socially this impact may be very great, especially in Nova Scotia and Newfoundland, and potentially for the whole of the eastern part of the country. The plan for marine development must therefore materially affect programs for our regional economic expansion. But it is essential that both social and physical changes be such that Canadians can take pride in them. The prospect of an ugly, unplanned and uncontrolled industrial activity, belching fumes into the air and pollutants into the water and onto the beaches, adding one more region of human blight to an already over-blighted eastern North American coastline, is repugnant. Some of the mechanisms necessary for control already exist. What is needed is a clear policy, and forthright program of action, to achieve a balance of industrial expansion and restraint. The control mechanisms are clearly outside the area of marine science and technology. However, in many marine aspects we simply do not yet know what the consequences of our actions will be, so we cannot intelligently effect control. The deliberate development of marine science and technology is thus an important aspect of the means of achieving our national goals. In fact, while the present level of our marine scientific and technological activity has achieved a certain theoretical appreciation of the oceans, it has not been sufficient to permit even a general description of the environmental situation which will be affected. To proceed with resource and secondary industry "development" without a simultaneous serious effort to obtain the very detailed scientific understanding of the ecosystem that environmental control implies would be seriously irresponsible. Clearly, this field of environmental quality control must be a third major element in Canadian marine science and technology programs for the 1970s.

The effects of our activities are, however, far-reaching. The review of marine science and technology problems in Chapter III has attempted to reflect some of our growing knowledge about the interactions of sea, air and land environment. It has become clear that environmental control does not mean simply the managed alteration of a single stream or bay, because the small effects generated there seem so often to act resonantly over a larger area and time. The evidence for at least cumulative effects in the Gulf of St. Lawrence is already great, and the fears for man's eventual effects on the Arctic may often be misguided in detail but are not substantially deniable. It is now time that we undertook the explicit study of these larger systems as total systems. With increasing evidence of our possible inadvertent inducements of climatic change, it is becoming of no small importance to assess deliberately and scientifically our capacity for climate control. We propose that the Canadian program in marine science and technology in the 1970s include a deliberate study of the feasibility of climate control.

To carry out a program with the objectives envisaged here requires a special balance among the efforts directed to basic and applied research, to development, and to industrial application. It requires that the various aspects of the balance of these efforts be accepted by university, government and industry as important parts of their total functions. In this chapter we discuss the roles of university, government and industry in promoting a balanced marine science and technology program, and describe in more detail two additional major projects which we believe they must jointly undertake as national projects.

Relations among University, Government Laboratory and Industry

When considering any topic that is influenced by the immensity of the physical size of the country, Canadians almost always remain aware of the limitations of human and financial resources that they are able to deploy. Nevertheless, in this awareness they must beware of too simplistic a view of efficiency. Most human activities involve a sort of commerce: co-operation for special purposes among people with different motives. In a buy-sell transaction no one expects the motivation or ends of the buyer to be the same as those of the seller. The transaction is symbiotic–advantageous to both but for quite different reasons. For some reason it seems not so obvious that the relationship between, say, a research worker and the organization that supports him, or even between industry and government, is usually of a similar kind. To neglect this probable fact, and to assume, for example, that it is either usual or desirable that research workers be motivated by the same goals as their supporting organizations, is to invite unnecessary confusion and unreasonable disappointment. To insist upon it is to invite mediocrity. This situation needs to be borne in mind when considering the roles of university, government and industry in marine science.

The University Laboratory

A university professor of science or technology[1] is motivated in his choice of the university milieu by various admixtures of desire for knowledge, desire for prestige as he sees it, interest in teaching, escape from the competitive pressures of the industrial world, and relative freedom in the choice of his activities. The society that supports him does so because it believes that at least some of the people he teaches are thereby better able to serve society, and that some of his activities lead to results of use to society. Rarely does the professor think of himself in these terms (except when he is asking for additional research support or additional remuneration).

The best of the professors use the freedom of the university to let their imaginations range widely. As a result, a high proportion of really new ideas originates within the university. It is a natural home for research. However, there is in this university system a high growth potential. Like organisms, professors instinctively behave so as to reproduce themselves, and tend to transmit not only information but attitudes and life styles. If we take it that the main impact from professors is upon graduate students, and that it is the products of the graduate schools that chiefly determine the course of science and increasingly determine the course of technology, we may concentrate our attention upon this aspect of education. Typically, a professor of science or technology will have three or four graduate students at a time working with him. Typically, it takes from four to five years from first to final degrees. Thus, a professor is capable of reproducing himself professionaly at a rate of nearly one a year. Since his professionally reproductive life span is likely to be about 20 years, such fecundity obviously incorporates a real danger of population explosion.

[1]For a professor in the humanities the situation is somewhat different. Unless he has private means, where else can he practise his profession but the university?

Such growth can be tolerated by society only when the need for this particular species is growing abnormally rapidly–and then only for a few "generations", in this case a length of about five years. The population growth must be restrained in the ordinary biological way. That is, if university research is to be continued and enhanced, there must be a decrease in the rate of reproduction of professors by reducing the output of graduates per professor, or most of the offspring must be placed in such a position that they cannot reproduce. A combination of the two mechanisms seems indicated.

Reducing the output of graduates per professor without inhibiting university research could be accomplished by deliberately increasing the duration of graduate studies. However, the use of such an artifice is not only inefficient and expensive, but poses such disadvantages for the student that we reject it as unacceptable. There are two acceptable devices, both of which should probably be used. First of all, a larger number of postdoctoral fellowships could be provided in both university and government laboratories. The postdoctoral fellowship is an especially desirable means of increasing the background of graduates prior to employment. Furthermore, a substantial increase in the number of postdoctoral opportunities would have another desirable effect. In any one field within marine science, the number of graduates per year, besides the number of positions available for graduates, is rather small. Just normal statistics will case large fluctuations in both, quite apart from the effects of such things as periodic government austerity programs. The group of postdoctoral fellows can thus be regarded as a holding pool, which can be expanded or contracted as these fluctuations in supply and demand require. "Holding" at this level is much more satisfactory to the individual than at the pregraduation level.

In the second place, it is possible to increase the availability of technician support in university oceanographic departments. Postdoctoral research projects are typically limited to about two years, and increased technical support of both postdoctoral student and professor would enhance the complexity and scope of projects that would be undertaken. A combination of these two devices is highly desirable and should be given close attention by granting bodies.

The second alternative–that of making graduates non-reproductive–leads to the logic that most of the products of graduate schools should not go into the universities. That is, a sizable fraction of the total scientific effort should be outside the university. Of the graduates, only those whose motivation towards working in the university environment is very strong should aspire to become professors. This argument has some implications for university management. In the first place, the professor must recognize that most of the people whom he has as graduate students are not themselves going to become professors or even research workers. For example, as discussed below, there is a need in government service for a large number of people of high competence who are well trained but whose abilities lie more in the field of application than in creation. This fact should be kept consciously in mind when selecting and training graduate students. In the second place, the university must be assured of a stable and long-term supply of funds and flexibility in their use, sufficient to provide support for students whose main aim will not be high academic standing and scholarship but excellence in a field of practical importance. Many of these students may not qualify for academic scholarships. (Some will; there is far from a one-to-one correlation between the kind of mark-getting "eye-on-the-ball" attitude that gets scholarships and the creative imagination that produces real scientific advances.) Granting bodies will necessarily have to place more emphasis on the support of "relevant" research.

But whatever the types and numbers of graduates produced, one of the most difficult problems faced by the university is the stability of the market for its products. Grants for graduate students are easily obtained during periods of an expanding economy. But with a lag period of the order of five years for advanced training, many of the graduates face periods of economic recession and reduced opportunity for employment. The new recruitment of students is slowed down at this time and they are then in short supply in the next expansion period. The university thus seems perennially to be out of phase with the employment system. The situation has been serious recently, and at times in the past. If we are not to lose a high proportion of our most highly trained graduates, there is a need for reconsideration of granting and long-term hiring policies by government. At present, a very large proportion of marine scientists find employment in government laboratories. We would hope that as industrial activity grows, this proportion will decrease. Nevertheless, the impact of recruiting for government laboratories is likely always to be large upon the graduate schools in marine science. To promote the orderly development in marine programs during the 1970s, it is essential that we find solutions for this problem. In the next chapter we discuss administrative mechanisms which would admit such solution.

When discussing marine science with respect to the university, it is necessary to make a clear distinction between training for professional work in the science and using marine examples as part of the necessary education in a field. The outstanding example of the second type is biology. Marine biology, both zoology and botany, is such an important part of biology as a whole that it is fair to say that a biologist's training is incomplete without considerable knowledge of it. It is for this reason that we most strongly endorse proposals of eastern and western universities for special field laboratories at St. Andrews, New Brunswick, and Bamfield, British Columbia, respectively. As we see it, the *principal* function of these field laboratories should be to serve as an essential facet of the undergraduate training of biologists, although they could be usefully employed in certain types of graduate student projects which do not involve major time-dependent variables. The faculty associated with these laboratories must, of course, have research interests. It is our opinion that these research interests should be concentrated upon near-shore phenomena, not requiring support by research vessels larger than launches.

A similar case might be made for geophysics. No contemporary geophysicist could be considered well educated without some information about sea floor spreading and other aspects of marine geophysics. However, these developments in geophysics have been so recent that the geophysicists themselves have not yet decided how the marine aspects should be fitted into their educational programs.

For the other fields, on the whole, the marine aspects are less central. It is no disgrace to a physicist, chemist or geologist to know nothing whatever about the marine aspects of his field. Thus, for example, the University of Alberta does not need a physical, chemical or geological oceanographer on its staff. (It does need marine biologists, and at least some of its geophysicists must have a real understanding of marine geophysics.) This is *not* to say that a physical oceanographer would not be most useful on the staff of the University of Alberta. Oceanography provides a fine example of contemporary continuum physics; a man capable of providing oceanographic examples in undergraduate teaching can enrich that teaching. Similarly, a chemical oceanographer is familiar with situations of a complexity rarely encountered elsewhere, and can provide valuable insight to chemists. A good theoretical physical oceanographer would be a valuable asset to any applied mathematics department. He is familiar, for example, with very sophisticated uses of singular perturbation theory, and in his assortment of wave-wave interactions, he can find examples for the treatment of non-linear equations superior to almost any others. Thus, a graduate who has completed a thesis in the oceanographic field should be able to compete on at least an equal footing with those from other fields for academic positions in universities and colleges. This must be borne in mind when considering the demand for people with training in the marine sciences. It may provide a demand fully comparable to the purely professional one.

The presence of faculty members with marine interests in universities other than those in oceanographic centres raises the problem of what their research opportunities should be. It is our contention that deep-sea oceanography should, certainly for the present time, be confined to the existing Institutes of Oceanography which operate in conjunction with the government laboratories and must receive large ship support from them. This leaves two alternatives for these other staff. The first is that they could associate themselves with biological groups at their own universities to work on near-shore phenomena. Such work will become increasingly important to problems in pollution detection and control. Where appropriate, government laboratories, such as the Biological Stations at St. Andrews, New Brunswick, and at Departure Bay, British Columbia, might well discharge some of their responsibilities in this area by contracts with the permanent staff of marine stations or with visiting professors. Similar government contracts might well be used to support projects that could be done at the Marine Science Research Laboratory at Memorial University.

The other alternative, which need not be exclusive of the first, would be that marine scientists at other Canadian universities find summer work at one of the existing university Institutes of Oceanography or government laboratories. There may be difficulties in directing graduate student research under such conditions, but the problem is not insurmountable, as McGill University has demonstrated in its growing relations with the Bedford Institute. University fund-granting agencies and government departments may find it advisable to make special financial provisions to promote such visits.

While it is essential to clear the way for increased marine research in Canadian universities by loosening the dependence of the university research program on the production of graduate students, the main function of the university must still be the education of future marine scientists and engineers and the creation of a cultured lay public, well-informed about the impact of the sea on our society. There is an encouraging improvement in general education aspects of the marine world, although Canadians have not been as active as is desirable. On the other hand, there are still serious deficiencies in the area of advanced professional training.

That gaps in our training programs can be filled effectively and quickly has already been demonstrated by the success of the present Institutes of Oceanography at the University of British Columbia and at Dalhousie. This development was begun at U.B.C. in the late 1940s, but at Dalhousie only in the late 1950s. At the present time, we find that the scientific quality both of the Institutes and of their products ranks unquestionably among the very best in the world, hence our ability to produce the best in marine scientists has an adequate base. With limited growth, the balance of training could be nearly ideal. Our present problems in scientific training are largely those of establishing the proper supply-demand ratios. The situation is, however, far from satisfactory with respect to the production of professional ocean engineers. Every industrial enterprise attempting to assess its opportunities in the sea is concerned first with how to obtain expert technical knowledge of it–where to find the technologists with the requisite experience. This is equally true in government, where there are requirements for technical experts to deal with defence installations and operations, fisheries construction and operation problems, and control problems related to corrosion, pollution, transportation, beach erosion and a host of similar activities. What they find is that the present cadre of experts has been self-made, and the supply is limited. The present production of recruits to the technological area is certain to be far behind the demand in the 1970s.

We have discussed this problem with various university, government and industrial staffs across Canada. There is agreement that the need is great although, following the sudden change in economic climate of the past two years, no one seems willing to commit his institution or agency to a firm statement as to how many people, with what kind of training, are needed. Explicit adoption by the government of a policy of marine industrial expansion and environmental control, such as is suggested by this report, would clear the way for joint university-NRC action to fill the need. In that event, there is a clear consensus that graduate training in oceanology (i.e. ocean engineering) should be set up in relation to existing Institutes of Oceanography. This training should perhaps initially consist of a series of intensive refresher courses, offered by the universities to graduate, experienced engineers. Such courses would be especially valuable if they concentrated on informing managerial level engineers in Canadian business of the technical aspects of marine operations and opportunities. Soon, however, these seminars should be developed into a year of graduate special engineering leading to the Master of Engineering degree. The merits of introducing oceanology at the undergraduate level have been much discussed, and this practice has already been developed with indifferent success in some universities in the United States. We do not believe that there are appreciable benefits to be expected from any real dilution or increased specialization of engineering at the undergraduate level. However, we do fully approve of efforts to incorporate marine examples in the training of engineers, as is proposed at Memorial University. The administrative aspects of marine technology are discussed in more detail in the next chapter.

Government Laboratories

The motives of a government in setting up a laboratory are usually fairly clear. There is a job, or a class of jobs, that it wants done. These are in the applied research and development categories, almost invariably. Hardly ever does the *motivation* include basic research. However, the motivation of the scientist working within this laboratory is likely to be quite different. He is much more likely to be motivated by such things as the sheer intellectual challenge of a particular problem within the science and by his own restless curiosity–a characteristic very highly developed in all good scientists. Where the general question that the laboratory is supposed to attack is sufficiently intellectually challenging, a mutually advantageous relationship may be established. However, there are two problems.

The first and most important is, in its broadest terms, a problem of communication. The language used by society to express its goals, such as greater prosperity, higher product yields and profits, and so on, is not the operational language used by the scientist in designing his experiments or reporting his results. In fact, it is not a language that the younger scientist has often encountered in his school or in his professional university training, or which has served to express his motivations in choosing a career in science. Unless the translation can be made effectively and imaginatively, there is likely to be trouble. All too often, the government laboratory director chooses to discuss his terms of reference in quite literal social terms because so many of his activities are concerned with justifying his program to financial administrators or the public at large. If, at the same time, the persons of less imagination in the laboratory–frankly, the less good scientists–choose to accept this literal social framework for problems without adequate translation into the working language of science, the resulting work becomes routine "fact-finding" or "fire-fighting", devoid of intellectual challenge, and is easily recognized as a scientific output of inferior quality. The second problem is really a corollary of the first. Governments establish laboratories for particular purposes, and expect special kinds of information from them, usually about a specific environment or particular complex process. The very large effects of time-dependent variables in a given area often implies the accumulation of large amounts of data over considerable periods of time. This special requirement often means that the less imaginative individual with training in the science finds a ready market for his services. The requirement is, in fact, so general that government laboratories tend to employ relatively large numbers of such individuals. If the leadership of such groups is lacking in the ability, imagination and drive necessary to cope with the analysis of large amounts of data, the whole program bogs down in an endless accumulation of data series, undigested and often indigestible.

Once the scientific questions become obscured by misuse of social language, or the burden of data collection overtaxes the staff of the government laboratories, the resulting inferior science makes new recruitment of good scientists impossible. To avoid these problems seems to require attention to at least two important features. The first is the creation of a sufficiently large and stimulating intellectual community which, in many cases, may suggest an association of several laboratories with related interests but different goals, often in proximity to a good university. (The Halifax-Dartmouth complex is a good example.) The second and possibly more important, though not so well recognized, is that the government agency must attract and retain the services of a few minds which are searching, curious and restless. This not only is essential to the scientific vitality of the laboratory, but also provides an essential bridge to the related laboratory, and the university. To keep them, the agency cannot expect them to work on routine problems. In fact, it does not want them for this purpose. Rather, it wants them to extend and deepen their insights within the broad area of the laboratory's responsibilities. They should be gadflies, constantly demanding intelligibility of the data collection. They may also be able to assist in the essential role of translating the problems of society into the operational language of science, and in the parallel task of retranslation of laboratory results into the objectives of society.

Not all these functions can often be found in a single individual, but it is those in whom curiosity and response to intellectual challenge are the prime motivations who are the keys to keeping the system functioning. If the laboratory is unable to permit these individuals to satisfy their curiosity, regardless of whether or not this can be confidently predicted to lead to results of direct relevance to the social reason for the laboratory's existence, they will simply leave. There are other places that will use their services.

The need for stimulating idea men in enabling governmental research organizations to respond, regroup and adapt to new challenges has in the past been recognized in Canada. The trend toward establishment of government marine research laboratories in association with universities (see, for example, a policy statement of the Fisheries Research Board, *The Fisheries Research Board and its place in Canada's scientific development 1968-1978*, Ottawa 1968) is a gratifying positive step toward its continuation. Other steps that we believe are needed to help sustain the level of quality of government research are discussed in Chapter VI.

In the present day of "revaluation of all values", however, the question is still asked: "How much of the total government direct expenditure in research can and should it devote to so-called basic research?" The answer clearly varies with the circumstances, but a knowledgeable review of this problem as it concerns industry has recently been given by a distinguished industrial research manager[1] in the course of the Noranda Lectures held at Expo '67. Government appears to have much of value to learn from industry experience where the problems of cost-benefit are clearer.

Based on experience at Union Carbide, Kinzel postulates that an expenditure of about 30 per cent of the *research* dollar on basic research was appropriate for large industry. Government research, while generally as mission-oriented as industry, has nevertheless broader objectives, and needs to support activities that require considerably longer pay-off times than industry can afford. An even greater ratio of government basic to applied research would not appear unreasonable, based on experience and observation of the more vigorous research laboratories. However, any formula is crude at best. Most of the pay-offs of science into technology and industry seem to have their origin in good research conducted in the classical scientific disciplines. Rarely can they be predicted from the original objectives of research programs, except by hindsight.[2] The well-known Halifax process for the production of fish protein concentrate is an excellent example. The Fisheries Research Board scientists were, in fact, looking for a process for the extraction of fish *oils* so that they could carry out analyses. It was a strictly scientific project. So efficient did they become in extracting oils that the *residue* was virtually pure fish protein. Many advances involve this kind of serendipity. Where the genius comes in is in recognizing the nature and possibilities of such strokes of fortune.

[1]Kinzel, A.B. Industrial research: why, who and what. Man and His World, The Noranda Lectures, Expo '67. University of Toronto Press, 1968.

[2]Report of the U.S. National Science Foundation. Technology in retrospect and critical events in science (TRACES). Washington, D.C., December 1968.

In planning science, the concern of central government administrators is not with what is "basic" and what is "applied". It is, rather, to establish objectives such as are outlined in the introduction to this chapter and to develop the structure for implementing programs. It includes the selection of research managers–the laboratory directors. The laboratory director must distribute the responsibilities for research projects among his staff according to personality, ability, performance and the requirements of the objectives of his total program.

However, the problem of the government laboratory is not merely to initiate a vigorous independent research program balanced between the basic and applied elements. The laboratory activities have a mission, and this necessarily involves a concern with what is generally called "development". This term again is so difficult to define precisely that most of the statistical information on science treats research and development as a single entity. But this phase of scientific research activity is an essential part of the process of making the results of science useful to society, either to meet management responsibilities or to exploit industrial opportunities. To carry out a balanced program, the research director must not only become involved in the implications of the work of his own laboratory but also keep open the lines of communication with university laboratories and industry.

This keeping an eye on both the developments in the science and developmental possibilities in industry or in government service is a difficult and often thankless job for the government science director. He must develop a "balanced" program, in the sense that the probings for new factual data and new scientific information must become neither so "factual" as to be intellectually sterile or out of date, nor so "scientific" as to be considered unrealistic, abstract, and "wasteful of the taxpayers' money". In some respects the problem becomes that of balancing the research man's inclination always to see the parts of the problem that could and should be further studied against the manager's simpler interest in getting the best answer that can be given *now*. While the scientist wants to work on a 95 per cent probability, the manager must often be prepared to work at the 50 to 60 per cent level. The *best* ways of resolving the different approaches are a continuing source of conflict, and much of Chapter VI is addressed to an examination of its many aspects, together with some important, if partial, solutions. However, the special relationships between the laboratory and industry are of such importance to a successful overall program as to require further discussion here.

Science and Industry: The Scientist-Technologist Symbiosis

A number of questions, social and scientific, are at any given stage in the development of science and technology within range of solution. Typically, the solution requires the development of new techniques or instruments and the addition of a certain amount of new scientific information. In the era of the 1970s, the question of pollution control provides a good example. What criteria can be used as an index of pollution? In most cases, science can now give an answer of sorts, but not a definitive answer. Given a criterion, technology can set up a measurement system which provides an index. However, continued research follow-up, making use of the now available data on the index, may show the necessity for scientific redefinition of the criterion. That is, the science-technology complex is a kind of circular-causal system, and scientific results cannot generally be thought of as ever reaching a stage of being totally transferable to a development phase. Attempts to divorce the application of results from re-examination in the light of new experience and of new scientific development in related fields lead to inferior technology and obsolescence of products.

This is a phenomenon now well recognized by industry which, in addition to hiring increasing numbers of engineers, finds it advantageous to employ scientists as well. Marine science provides some examples of this growth of research in industry, particularly in the food products and pharmaceutical areas and in development of special electronic devices in dealing with problems of marine fouling and corrosion, etc. Scientists and technologists in these fields are, however, essentially extending to marine situations chemical and physical processes and techniques developed in classical terrestrial science. Oceanographic research and development, on the other hand, deals with the oceans as a special environment. Research activities do not readily fall within classical disciplines. In the oceans, on the one side, there is general ignorance of the patterns and processes of change. On the other side, there are the special qualities of a medium in which man cannot live freely. In this dense and dynamic but chemically and biologically dilute environment, the facile application of land-based knowledge or skills leads often to frustration or ludicrous results. It seems that the variety of problems that must be faced and overcome before even a start can be made has meant that, except in the case of the potentially large pay-off and the relatively simple objective of oil, the research and technological development requirements are beyond the capacity of single industries. In very many cases, the potential pay-off is so uncertain and so far in the future that industry has been unable to take any other stance than that of watchful waiting.

We are here faced with a situation, far from unique to Canada, with wide implications. That there are resources in the sea in great quantity is now beyond question. However, with few exceptions, the economics of the situation are so obscure, and the possibility of return so far in the future, that it is difficult for industry to act–taking into account the way in which costing is done in most industries. In many cases, then, the impetus must still come to industry through direct government action.

However, it cannot be expected that existing research institutions can carry ideas with potential pay-offs into the pilot-plant stage which would make it possible for industry to evaluate the economic prospects. For example, the new fish protein concentrate (FPC) process referred to above was developed by the Fisheries Research Board laboratory in Halifax, partly with the support of the then new Nova Scotia Research Foundation. The scientists responsible had reason to believe that it offered real prospects for economic payoff. However, the development money needed for study at the pilot-plant scale was not available from within the Fisheries Research Board or Department of Fisheries budget, and the economic position of the fishing industries was too precarious to permit its active participation. The development and innovation study was eventually completed in the United States under a series of fully funded development contracts. The process adopted was the Halifax process. While it is a satisfaction that a private commercial FPC plant is now being built by U.S. industry in eastern Canada, this result was not a consequence of our ability to make use of research results. It indicates, rather, that we have lacked an adequate mechanism. It is ironic that even now there remain many aspects of the FPC problem which need development but no such work is being done in Canada.

There are a number of things that could be done now to bridge this gap, which is not at all peculiar to the fisheries field. For example, it is clear that to the government institutions must fall the major responsibility for the large number of explorative surveys necessary to outline what we have. However, the government responsibility is primarily to guarantee the quality of the work and to see that it gets done. It does not have to actually carry it out. There is obviously room here for contracting out to industry survey teams. In Canada this applies equally to hydrographic survey and geophysical and geological surveys. The advantage of such contracts is that it creates qualified teams who can then carry out for industry the much more detailed survey that must precede investment. The way to do this, however, is not easy to find. In hydrographic survey, large teams of trained experts, large ships and expensive equipment have been developed to carry out the exacting and careful technical work. Contracting out means first of all finding a company ready to make a sizable capital outlay. The department must then be able to issue a minimum guarantee to permit the operation to get started. This means a sizable increase and long-term commitment of its own funds, without a significant initial cut-back in its own staff since the new service may at first be inefficient and require supervision. The required concerted action among several departments and levels of government makes it difficult to initiate the process from within the hydrographic service, despite the fact that the responsible officers have already demonstrated their sympathy for the system by issuing major contracts with universities willing to assume the development of better analysis of data and computer production of charts.

Recently, the Atlantic Oceanographic Laboratory in the Bedford Institute did take steps to issue a contract for geophysical survey with a private company. However, the problems faced by the company in getting started before this contract only underline once again the inadequacy of our present mechanisms. It must be clearly recognized that decisions for investment directed to commercial returns can best be seen and grasped by industry. In our present situation in Canada, this requires a considerable development of both research and technological capacity in the private sector. The program for the 1970s must make a deliberate attempt to have such industrial development parallel to the government and university efforts.

Government has begun some programs designed at least to take the first step of encouraging an increase in the research

Table V.1–Forecasts and Expenditures for Industrial Development Programs (in millions of dollars)

Program or Agency	1967-68		1968-69		1969-70	
	Forecast	Expenditure	Forecast	Expenditure	Forecast	Expenditure
IRDIA[a] (ITC)		2.1	31.3	19.6	34.4	5.5 (1st 6 mos.)
PAIT[b] (ITC)		6.4	9.0	4.3	11.0	1.7 (1st 6 mos.)
IRAP[c] (NRC)	6.9	6.4	7.3	7.1 (committed)	6.8	?
DIR[d] (DRB)	4.5	4.5	4.5	4.3	4.5	(4.3)
DIP[e] (ITC)		22.9	32.0	30.1	37.0	11.6 (1st 5 mos.)
Other[f] (DND)		24.8		28.8		26.3

[a]Industrial Research and Development Incentives Act (ITC). Data from Commons Debates, December 17, 1969, pp. 2066-2067.
[b]Program for the Advancement of Industrial Technology (ITC). Data from Commons Debates, *ibid.*
[c]Industrial Research Assistance Program (NRC). Data from NRC brief to Science Council Study on Aeronautics.
[d]Defence Industrial Research (DRB). Data from Senate Committee on Science Policy, No. 4, p. 435, and from DRB (personal communication).
[e]Defence Industry Productivity (ITC and DND). Data from Commons Debates, *ibid.*
[f]DND support of R & D in industry. Data from Senate Committee on Science Policy, No. 4, p. 600, and from DRB (personal communication).

and development (R & D) growth in Canadian industry. Separate statistics for the marine-oriented industry are not available, but Table V.1 shows recent estimates of total expenditures under these programs.

From the table it appears first of all that the civil programs administered under the industrial research program of the Department of Industry, Trade and Commerce, and designed to enlarge R & D activity in industry, have not apparently been taken up by industry even though the forecasts indicate that the policy of government was to enlarge them. The direct research grants of the National Research Council and Defence Research Board for specific research projects programs were, however, quite successful. So too were the more defence-production-oriented grants made by the Departments of Industry, Trade and Commerce and National Defence.

A number of reasons for this situation are advanced in a Science Council Special Study[1] and so we do not treat them in detail here. The nature of these programs has been changed in response to criticisms, but from the point of view of the present report, what is important is that civil R & D expansion programs might be expected to have little impact in the marine area where a particular research or development program is expensive, unless the company is capable of quite large investments and is assured of a major share of market potential, or where the proposal in some sense already specifies a market. This latter situation characterizes most of the defence programs where specific articles or instruments are under development and are for purchase by the Armed Forces; a large share of the industry R & D investment in them is underwritten by the government agency. This suggests that, at least initially, in the process of marine civil industrial expansion, it is necessary to carry several major projects through from research and development to the actual manufacturing and marketing stages by deliberate and planned action. In our opinion, based on an extensive survey of the marine field during this study and backed by briefs from several active but unrelated marine-oriented companies, the federal government must immediately take the initiative by creating a special Canadian Ocean Development Corporation specifically

[1]Wilson, A. H. Background to invention. Special Study No. 11. Science Council of Canada. 1970.

charged with planning, funding and administering special joint science-industry projects. More detailed consideration of the reasons for this choice and suggested terms of reference for the corporation are given in Chapter VI.

Two Major Areas of Concentration for Canadian Marine Science

It will be evident from the foregoing that marine science and its technological aspects have many ramifications. The rapidly growing activities of industry call for many scientific services in the fields of survey, forecasting, and improved methods and facilities. There are new calls on marine science for information and methods that can permit improved management of the natural resources, prevent pollution, and enhance the quality of our total environment and show the way to new industrial opportunity. All these and more make heavy demands on the scientists and engineers in universities, government and industry.

It is not a simple matter to co-ordinate these various programs, and it is not especially desirable to attempt a complete co-ordination. Nevertheless, gaps in communication and sense of purpose have appeared and are bound to appear in the future. To minimize these difficulties, and to promote achievements in the science and technology in which not only the professionals but all Canadians can have a sense of interest and pride, we have concluded that a significant proportion of the total marine science and technology effort in Canada should be directed toward a few clearly identifiable major objectives, attainable in reasonable time.

In what follows we outline two projects which we believe to be of real scientific as well as social significance. In each case a variety of skills and expertise is required, hence experts from many different agencies can participate. It is expected that in each case the technological "know-how" generated by the work will be applicable to attacks on related problems. Indeed, this kind of "fallout" is a central motivation for proceeding in this way, and care must be taken that the organization of the work be such as to encourage it.

1. The Ice Cover of the Gulf of St. Lawrence

We have already noted that modifications of the flow rates of the St. Lawrence and other rivers of the area appear to have had an appreciable effect on the Gulf of St. Lawrence. It is likely that these changes have already had effects on the ice cover of the Gulf. But it is our opinion that judiciously designed engineering works could bring the ice cover fully under control. Its amount could be determined at a political rather than a "natural" level. Not only can the timing of freshwater inflow be adjusted, but the amount and nature of the flow through the Strait of Belle Isle could be controlled, as could much of the mixing between the deep saline and upper brackish water. If the most "sensitive" features of the system can be identified and modifications made there, it is probable that the cost of control could be kept moderate.

Control of the ice cover would provide the world's first serious test of the possibilities of deliberate climate control. Changes in the degree and timing of ice cover would affect such important, or potentially important, aspects of the Canadian economy as Gulf shipping, the New Brunswick and Newfoundland forest industry, the Gulf fishery, oil drilling in the Gulf, and the agricultural and tourist industries of Prince Edward Island.

A theoretical study of the economic and social implications of various degrees of ice cover should be undertaken. If, as appears likely, a reduction in the ice cover would be economically and sociologically advantageous, oceanographic and technological study of the methods of controlling the ice cover should be carried out. It would then be possible to see whether the cost-benefit ratio for such an activity would be favourable. If so, we should not hesitate to carry it out.

This study of the ice cover of the Gulf of St. Lawrence is suggested because of its immediate economic importance, the accessibility of the Gulf to present oceanographic establishments, and the fact that the present ice cover provides a convenient place for study of many of the ice problems which will be encountered in the Arctic. Of particular importance, however, will be the knowledge gained about the influence of freshwater runoff on ice formation, weather and climate. In this sense the Gulf study is an important model for what may be much more difficult and sensitive problems in Hudson Bay and in the Arctic itself.

There are strong economic pressures in North America to utilize the flow of fresh water which currently enters Hudson Bay. This might be done by diverting much of the flow southward for Canadian use or even for sale. But, as was pointed out earlier, it is certain that the low salinity water produced by present flows into the Bay is a major factor in ice formation, the nature of the ice and its persistence. The degree of ice cover has important side influences, among others, upon the climate of surrounding land areas. It is quite possible that the ice cover of Hudson Bay could be deliberately altered to our long-term advantage. It may equally well be blindly altered to our ultimate disadvantage. On a still larger scale, the U.S.S.R. has fully developed plans for diverting some of the major Arctic rivers southward towards the Caspian Sea. We must be prepared to assess what impact such major diversions could have on our climatic conditions as part of our consideration of major hydrological projects on land. The obvious importance of these joint hydrological-oceanographic-atmospheric programs to the nation suggests that an approach to them through the Gulf study should form an important dimension of our national science program.

2. The Management of the Strait of Georgia

In Chapter I we noted that conflicting interests of both land and water use of the Strait of Georgia area are already inhibiting development there. This region is unique in Canada in having the only really major concentration of population on a sea coast. The city of Vancouver is one of the most rapidly growing urban centres in Canada, but one where the total living space is severely limited. The rate of growth in the demand for recreational opportunity is therefore especially great. In this situation, the sheltered sea waters from the region of the Gulf Islands in the south to the Hecate Straits in the north are certain to play an important part.

The region is, however, rich in natural resources other than recreational opportunity. It is the traditional site of a large fishery. It is a major transportation route for timber, and contains the most important port on the eastern edge of the Pacific Ocean. The northern part of the area supports one of the largest concentrations of native people in the whole country, and they are strongly dependent on exploitation of fisheries and forestry for their living. The area could be a site for offshore production of oil. It is liable to many pollution hazards.

Oceanographically, the Strait is dominated by the outflow of the Fraser River. This large freshwater source, with its load of silt, minerals and organic materials, flows into the Strait through three channels cut through the large delta it has built. Its effect can be traced in much of the surface water of the region to its discharge through the passages. It mixes with a large amount of deeper water which has a strong bottom inflow to compensate for the outflow of entrained brackish water at the surface. The combination determines the rich biological productivity, and the flushing action dilutes and discharges potential pollutants.

This system has been studied in some detail by various scientific and engineering groups for a number of years. But while the main features of the oceanography are known, the time dependence of various phenomena are not, nor is the dependence of biological production on the various physical parameters or on pollutants. Past studies have been primarily directed toward requirements for managements and maintenance of the commercial fishery. A comprehensive knowledge of the interaction of various natural factors and of man-made influences on them is lacking.

In view of the rapid growth of population in this area, the social objectives for use of this system and its resources will change at an increasing rate. Furthermore, it is quite possible to deliberately change the oceanography of the region by engineering works which might divert or adjust the river discharge, by dredging or damming the passages or by shore installations. In the changing social context, some of these changes may be desirable, others would not. But a measure of their impact on the human environment cannot be assessed without a deliberate systems study. Studies that might form significant parts of such a deliberate overall appreciation are now under way.

Studies of a total environment have been considered in many parts of the world, and some steps towards them have been taken in the New York-Long Island and the San Francisco Bay areas, for example. However, nowhere does it seem easier and more profitable to undertake a well co-ordinated ecosystem management project than in this area. A joint undertaking by the provincial and federal governments, co-ordinating work in social, economic, engineering, and natural science departments of the universities, government research laboratories, and industry, could create a team of experts who would be in increasing demand in many parts of the world. That is, this area could be in the forefront in development of the new field of environmental engineering. Not only could this study, centring on the productivity of the waters and the economic and social value of alternative use, provide a model for future Canadian development; it could lead to valuable exports of the environmental engineering know-how acquired by groups of consultants.

While both the projects outlined above contain, as a central element, the study of a major oceanographic system, they include important elements of other environmental science studies, in particular, hydrological studies of major river systems and associated meteorology. They also imply a need for closely associated social and economic studies, since any major environmental alterations will have important effects on the surrounding land. For this reason we believe that the projects and their possible implications should be a subject for wide-ranging discussion. Such discussion might well take the form of a series of specialist and public seminars sponsored by various groups such as the Canadian Council of Resource Ministers, for example. The discussions would have as their objective the identification of various points of view and valuations concerning major ecosystem manipulation. At the same time, it would be appropriate for the federal government to appoint a special steering committee for each project. These groups could invite agencies in government, university and industry to submit proposals for research, on the basis of which it could undertake a feasibility and cost study. The department responsible for such a study should probably be one of the major operating departments of government. It must be placed in such a position that, after its study period of about two years, it should be able to recommend to government whether or not the projects could and should be undertaken. We refer to the administrative and organizational problems in the next chapter.

Chapter VI

Organization and Administration

In earlier pages we stated our view that marine science and some of marine technology must be regarded as part of the larger interdisciplinary field of environment science, to which we may in the near future add environmental engineering. Development of interdisciplinary sciences has been a recurrent phenomenon, so that there are now a number of predictable ramifications. The classical laboratory sciences find new problems which need to be studied from several viewpoints. The combination is soon recognized by universities which set up new interdisciplinary departments. In the course of time, the "interdisciplinary" aspect is forgotten. Biochemistry and biophysics are familiar examples, and we increasingly hear of biogeochemistry. When these new and old disciplines are applied to problems in the natural world, new combinations arise. Thus we are familiar with such terms as Agricultural Science or Fisheries Science. The organization of these fields has posed some problems for the university which has usually responded by setting up new departments or institutes or even whole faculties to cater to the new demands.

We do not intend to discuss the organizational problems of the university here. What is important is that the same process inevitably affects organization in government as well. As we learn more about any subject and begin to be able to apply knowledge gained from interdisciplinary science more and more broadly, the classical functional divisions which governments make among departments become fuzzy. The reasons for departmental existence may at first be redefined. Departments then become partially or wholly recombined. Finally new, more or less formal, interdepartmental committees and structures appear. In the scientific fields supported by government, these have in some instances been given considerable autonomy. Interdisciplinary sciences almost always have strong applied aspects. When a large and identifiable interdisciplinary science becomes firmly established, the government planner becomes aware that there is a proliferation in the number of departments interested. This proliferation cannot be contained; instead the planner must become sensitive to the needs for a parallel in the governmental organization.

This situation has certainly developed in the marine science and technology area. In a brief submitted to our study, a federal government department estimated that in Canada there are more than 30 federal agencies, 5 universities and approximately 100 companies significantly engaged in marine science and technology activities. Following our study we now believe that this underestimates at least the university and industry side, and to the total must be added a considerable number of provincial agencies. However, the many aspects which a concern for the sea raises, within such a comprehensive functional organization as the federal government, are well exposed by these figures. It is also clear how very difficult it becomes to obtain a single comprehensive statement on policy for marine science and technology or to generate a program which can be co-ordinated to satisfy all requirements.

It is possible to react to this situation in two extreme ways. One is to insist on development of a single agency, speaking with a single voice and operating an "integrated" operation for the sea, based on the fact that it exists as a unique environment. In this arrangement, the traditionalist would find some odd bedfellows as functional partners. However, it is the kind of solution which was developed by the Canadian Government for the Armed Forces. It is also the solution recommended by the United States Commission on Marine Science, Engineering and Resources[1], on the basis of a very comprehensive and intensive study. If the United States does adopt this recommendation, its future experience may yet provide us with valuable precedents. It is

[1]Our nation and the sea: a plan for national action. Report of the Commission on Marine Science, Engineering and Resources. Washington, D.C., January 1969.

not, however, a step which we believe is either necessary or appropriate for Canada at the present time.

The opposite extreme is, of course, not to attempt any planning, programming or budgeting on the basis that a given array of responsibilities is concerned with the sea. This arrangement–or lack of arrangement–founders on the fact that most such responsibilities have many requirements in common. The absence of system may end up with an attempt to divide up a series of inadequate budgets according to local and parochial departmental priorities. The resulting resort to the "final control on money" cannot but lead to serious gaps and distortions in the effective development of our knowledge of the environment and policy concerning it. It is presumably partly in its attempt to circumvent such problems and to help prevent a future chaotic development that the Canadian Committee on Oceanography (CCO) requested that the Science Council undertake this study.

The problem was reviewed by the Glassco Commission[1], which recognized a requirement for marine research within departmental structures such as fisheries and defence. However, it also acknowledged special government interest and responsibility in oceanography "unconnected with direct operations". This responsibility had, before formation of the Commission, been accepted by the then Department of Mines and Technical Surveys through its formation of a special Marine Sciences Branch and the building of the Bedford Institute. Most of the needs recognized by the Commission have in fact already been implemented on the east coast of Canada and there are plans for expansion to the west coast. It is to the credit of the departments concerned and to the Commission that the arrangements are generally hailed by the scientific community as a resounding success.

[1]The Royal Commission on government organization. Scientific research and development. Vol. 4, Report No. 23. Ottawa, Queen's Printer, 1963.

But in the almost ten years since the study by the Commission, there has been a startling change in our situation. The growth of oceanographic knowledge has led us to the verge of very important applications. Thus the present Department of Energy, Mines and Resources, rather than being a central research-oriented executive organization operating research programs "unrelated to any department", finds itself with an opportunity and perhaps obligation to assist the country to "cash in" on major applications. As might be expected, the needs of many other departments for oceanographic information have increased correspondingly, and the means of making use of this knowledge involves responsibilities of many of them. The particular concern which we repeatedly stress here is the urgent need for effective mechanisms to achieve a technological transfer of this marine science and technology to a potentially large industry, and the means to encourage the industry, especially secondary industry, to a rapid and continued growth.

Perhaps, ten years ago, we did not really think it could happen. It has, and this fortunate result requires changes in organization which will permit the government to act. The course we recommend here calls for significant additions to the present system, but in many of its features is an extension and formalization of practices already begun. We believe they are workable and sufficient for the present, as long as key modifications are acted on rather quickly. However, this is an area which the experts on government organization might well re-examine five years hence in the light of further developments.

Top Management in the Federal Government

There are a number of reasons why the federal government must play a central role, most of them rather obvious. The whole field of activity is so broad that no other organization can comprehend its many aspects. In many particular situations, the conditions for successful operations, or their consequences, are so obscure or so complex that only governments can find the resources needed for long-term investments. But even where the objectives and the potential are clear, the lack of definition of international, national and individual property rights often requires that the federal government intervene to create the conditions which will permit exploration, exploitation and effective management.

The large number of federal agencies with significant responsibilities involving marine science and technology report through a total of 14 different ministers, if the Department of Treasury Board is included. The list of departments is as follows:

Members of CCO:

1. Energy, Mines and Resources
2. Fisheries and Forestry
3. National Defence
4. Transport
5. National Research Council (laboratories and support to universities).

Observer CCO:

6. Industry, Trade and Commerce
7. Public Works
8. Service and Supply
9. External Affairs
10. Indian Affairs and Northern Development
11. Secretary of State for Canada (National Museum)
12. National Health and Welfare
13. Regional Economic Expansion
14. Treasury Board.

The first five of these departments are responsible for operating permanent research establishments with direct interests in some aspects of research, related more or less closely with their other operational responsibilities. Almost all the others have needs for research information, and most of the first twelve have some marine developmental or research activity going on now, or had in the past. The principal research activities, most of which require some sea-going capacity, are co-ordinated under the Canadian Committee on Oceanography (CCO), an informal body consisting of top management representatives from the five federal departments noted. Each representative must have the authority to commit his agency to action. With them sit the directors of the four principal university "oceanographic" institutes (we include the Great Lakes Institute in this definition) at the University of British Columbia, University of Toronto, McGill University and Dalhousie, together with a number of observers.

The CCO is the successor to an earlier committee called the "Joint Committee on Oceanography" (JCO), which was established in 1945 between the Department of Defence and the Department of Fisheries in response to the fact that while the Navy required oceanographic information for its ship operations, Canada's only qualified oceanographers were employed by the Fisheries Research Board (FRB), which at the time had no independent sea-going capacity. The relationship appeared fruitful to both and resulted in the setting up, in connection with FRB laboratories on the east and west coasts, of oceanographic groups which could pursue oceanographic research needs of both fisheries and the Navy. The Navy supplied the ship support, Fisheries Research Board employed the scientists and provided their support staff and facilities.

Of course, oceanographic information is important for more than just Fisheries and Defence; for example, Transport became an early member of the committee. Provisions for the training of oceanographers also had to be made and the Department of Defence (DRB), in conjunction with the University of British Columbia, set up the first Institute of Oceanography in 1948. It became increasingly clear that the field had broad potential interest. When at the same time the then chairman of Fisheries Research Board resisted enlarging that organization to look after needs he considered to be outside his terms of reference (itself a remarkable event!), a major program in the physical science aspect of oceanography was undertaken by what is now the Department of Energy, Mines and Resources. This department was already involved in marine surveys through its hydrographic branch. It built and staffed a modern research facility at Dartmouth, Nova Scotia, and provided it with up-to-date oceanographic research ships. The effort was supported by the National Research Council through funding of the Institute of Oceanography at Dalhousie University. The National Research Council has now assumed the responsibility for most of the federal government funding of all four university centres. Certain aspects of the total program, of particular interest to defence, are developed separately within the Defence Research Board laboratories. Arrangements at the operating level are discussed in a later section of this chapter.

The Canadian Committee on Oceanography is an informal body, that is, it is without official legal status. It was formed (as the JCO) out of need for co-operation between a research and an operating agency of government. Its enlargement resulted from the recognition of the growing need for oceanographic knowledge. As the CCO, it has concerned itself with development of an oceanographic research program which could serve most of the departmental requirements which could be foreseen. From its history, it has been in large measure effective as a joint capability planning group under the general policy guidance of government, in that the Department of Energy, Mines and Resources is primarily responsible for the physical aspects and the Fisheries Research Board for the biological aspects of such a program. Its essential function has, in fact, been to provide facilities for research programs. This is accomplished largely through three regional working groups–one on each coast and one on the Great Lakes. These regional working groups consist of the heads of local government and university laboratories, and ship or aircraft operating agencies, their main function being to operate the "ship pools" which are described elsewhere. A fourth working group, "The Working Group on Ice in Navigable Waters", has operated in a different manner, its main responsibility being encouragement of special programs in ice research in areas such as the Gulf of St. Lawrence, Hudson Bay and the Great Lakes.

The Canadian Committee on Oceanography, as an informal voluntary body of senior officials, does not ordinarily question the rationale for a project proposed by a departmental sponsor. Rather, the members assess the value of projects in the light of their own departmental responsibilities and collectively. The CCO also offers opinions on the relevance of university projects to the various departments in the light of available facilities. University groups can then be offered facilities by one of the government ship-operating agencies. It has also assisted in the formation and operation of an integrated scientific research program which is generally agreed to be both scientifically commendable and socially relevant. The operation of the "Working Group on Ice in Navigable Waters" is perhaps an outstanding example of what can be accomplished without formal organization.

However, the program is not comprehensive of the whole field of marine science. Responsibilities which lie wholly within the terms of reference of the departments are developed within them. Discussion in the light of information on oceanographic programs compiled by the CCO secretariat (provided on a part-time basis from within departments) does provide an opportunity for the responsible participants to be informed on current programs, problems and needs. However, the CCO does not have the power to adjudicate jurisdictional disputes among its members or, except by persuasion, to change a unilateral course of action by any of its members. Proposals for funding are carried to Treasury Board by individual ministers, each of whom also has particular operating responsibilities associated with parts of the research program managed by his department. It is clear that this system creates difficulties in obtaining objective technical advice on what should constitute a national program in marine science and technology.

In addition, the Canadian Committee on Oceanography has restricted its deliberations to the research program. In the past this has perhaps been understandable. While there has always been a marine industry in Canada, it has been relatively small. Except for fisheries and certain defence aspects, this industry has not been especially related to research activities. The recent very large change in this situation, with the development of interests in offshore oil, has been the result of that industry's traditional links with the Geological Survey of Canada and its marine offshoot at the Bedford Institute. However, the departments concerned have very little association, and almost no mechanisms, for creating liaison with the potentially very large secondary manufacturing and construction industry which must now become involved. The CCO has remained aware of this situation and has invited representation from the Department of Industry, Trade and Commerce in its deliberations. Their representative, the director of one of the 38 divisions of that department, sits as an observer. The CCO secretariat has also begun the task of assembling information on marine industry research activities. It is apparent that these are not sufficient mechanisms for coping with the new and probably very large interests of industry.

As part of the mechanism for ensuring that government can take its full responsibility for encouragement of secondary industry, we believe it essential that the marine division of the Department of Industry, Trade and Commerce should be strengthened and enlarged. A number of government departments are doing excellent work in the marine field with remarkably small staffs. However, this appears to be an especially rapid growth area with important responsibilities towards the formulation and implementation of national policies.

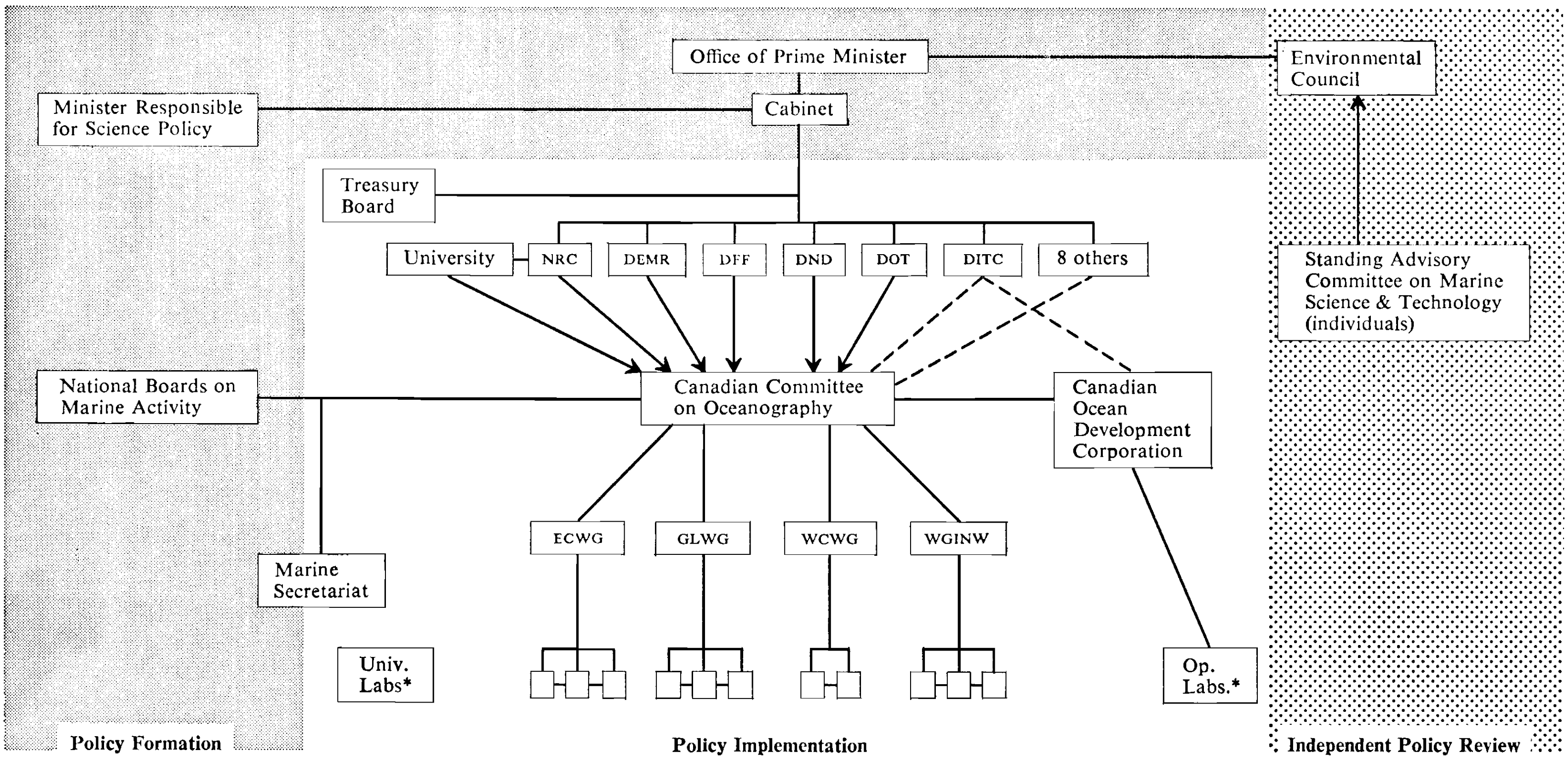
Marine science and technology quite clearly have important international aspects. The Canadian Committee on Oceanography has functioned as an adviser to the Department of External Affairs on suitable representation for Canada in international oceanographic affairs. Selections are made from both government and university ranks. Reports of activities are received and attempts made to take account of them in national programming, with appropriate departments sharing the load according to their capabilities and areas of responsibility. The very large aspects of legal jurisdiction and sovereignty are not considered by this committee.

It appears, however, that the approach to participation in international oceanography has been more *ad hoc* than is desirable. There has been no clear mechanism of policy formation which would permit government departments and universities to anticipate international requirements in their programming, and except perhaps in the case of the Department of Fisheries and Forestry, minimal feedback to the External Affairs Department on the scientific and technological problems which may generate new requirements for international involvement.

The CCO is an organization which can claim a considerable responsibility for the successful development of marine research in Canada. It has shown a considerable adaptability to changing conditions and an ability to "get things done" in its chosen area of operation. It has also shown a sensitivity to its own weaknesses. With its awareness of the recent rapid growth in demand for oceanographic information and service at a time of government austerity, it requested that the Science Council undertake the present study. In our review of organizational problems, we have had the benefit of advice from a majority of the members of the CCO, as well as from a number of other sources.

In Figure VI.1 we present a schematic diagram of what appears to us a minimum degree of reorganization required to meet present needs for developing and carrying out policy decisions in the marine area.

Figure VI.1



Note: To avoid confusion in the diagram we have not attempted to show the direct lines of communication which exist between the headquarters levels of the departments and their operating laboratories or agencies.

*The university and CODevCo operating laboratories interact with all other operating laboratories and working groups.

The central part of the chart, labelled policy implementation, represents the organization in much the same way as it exists at present. In the chart, the departments are represented in their functions as operating managers, meeting in CCO for the purpose of joint policy implementation. This assumes that the CCO is considering the implementation of projects which have been developed from requirements based on prior policy guidance. While the common ground on which these departments meet may be largely research, it is our belief that with appropriate policy guidance they can effectively extend this co-operation to fulfil some of the needs for development as well. However our main point here is that this group should be considered primarily as a federal government interdepartmental implementation agency. While university representation is most important, the university institutes themselves should reconsider whether it is worth their while to maintain full attendance, or whether they might maintain a rotational representation, while making their main contribution at the working group level. One of the principal functions of the CCO within the country must be to ensure that while the development needs of government departments and industry are served, the entire capability grows sufficiently so that the research effort does not suffer. It is the only interdepartmental body charged with judging the relevance of scientific marine projects in the light of declared government policy.

It was a central theme of the Glassco Commission report that operating organizations should be divorced from the formulation of government policy. Considerable technical knowledge and skills are required to support policy formulation. However, where an interdisciplinary area such as marine science and technology cuts across so many departmental functions, policy affecting the whole area can be developed only with great difficulty from within the various individual departmental policy and planning branches. In fact, it is difficult to see how this can be done at all in a committee of equals, each having different terms of reference, functions and resources, except in a situation of such rapid growth of the whole area that even large new projects are not too long delayed. A solution to this has been advanced in some other approximately similar cases, the simple expedient being to name the department with major responsibility to act as chairman-co-ordinator and interpreter of policy. While the same system might be followed here, we have rejected it on the grounds that no one of the the operating departments represented on the CCO is suited to actively discharge what seems to us to be the main task facing the government in the 1970s–ensuring that the results of a balanced marine science and technology program are made available to industry, and that deliberate use be made of such results to foster growth in the secondary industry.

As a part of the mechanism required to meet present conditions, we show on the left-hand side of Figure XI.1 the *National Board on Marine Activity*, a new governmental body responsible for recommendations towards policy formation. It is clear that this body must have much wider representation than the CCO. It is our belief that it might well be an honorary committee or board of some 15 members drawn from government, university and industry. Its chairman should be appointed by the minister responsible for science. The membership should include the chairman of the CCO and probably at least one other member from another department within the CCO. If the Canadian Ocean Development Corporation discussed below becomes a reality, a member of its Board of Directors should sit on the National Board on Marine Activity. It would be appropriate for an observer from Treasury Board to be present at all meetings. A representative of the Science Secretariat should be on the Board and may even have a special appointment as its chairman. This Board could best pass its recommendations directly to the policy-making level of government through the minister responsible for science policy.

Both the Canadian Committee on Oceanography and the National Board on Marine Activity will require considerable secretariat services. In the CCO, the Fisheries Research Board has traditionally supplied a part-time secretary and stenographic services. Additional support has been made available by the Department of Energy, Mines and Resources. This secretariat has prepared important position papers, compiled and circulated information on research programs and acted as secretary for meetings. Despite the prodigious energy and scope of the secretaries, the amount of work has become too much for this system and delays in production are beginning to result. It is our belief that this secretariat should be made permanent and enlarged to become the common secretariat for both the CCO and the National Board. A suitable organizational home for the secretariat would be within the National Research Council, pending possible formation of a Ministry of Science Policy which would seem the most appropriate location. While the position of executive secretary should be full-time, term appointments of three to five years might well be made from within various CCO agencies on a rotation basis.

The functions of the secretariat should be increased. During our study, we quickly became aware of the glaring lacunae which exist in information exchange. This was especially obvious between industry and the laboratories of government and university. Similar gaps exist between university and government, and between the development and research areas of various government departments. In general, information exchange within localities is quite good, but it is poor over a wider circle. For example information exchange within the Halifax-Dartmouth research community seemed good, but there is relatively little contact with Canadian industry. At the departmental level, it is not difficult to find staff of the Defence Research Board who are unaware of the Naval Engineering Test Establishment in Montreal, let alone some of the seemingly excellent work done by its vigorous and dedicated staff. When there is neither a departmental link nor geographic proximity, ignorance can be nearly total. Thus there is little discernible interaction between the groups working on the west coast and NRC groups working on similar problems in Ottawa.

Faced with this situation, we have formed the opinion that no library-type repository or circulation service of information will meet the need in present conditions. What is needed is an active technical information service group, consisting of two or three technically trained people with a generous travel budget. It should be their job to visit industry and laboratories to become aware of what is going on and what people are trying to make happen in marine science and technology in Canada. They should pass relevant information on to others. By their personal contacts they could actively promote the exploitation of those kinds of opportunities that only a stranger can see. Information services are a function of the National Research Council. It would be appropriate for that body's Scientific and Technical Information Group (STI) to take the initiative here. However, to be fully effective, we urge that this Technical Information Group–these peripatetic information officers–should have strong ties to the CCO secretariat. If both are located in NRC, this can be simply accomplished. Their relationship may need special action to re-establish it if the secretariat were to be transferred to a Ministry of Science Policy.

While it is not necessarily an integral part of the regular policy formation and implementation bodies, we wish to draw attention here to our suggestion in Chapter II that there should also be formed a Continental Shelf Committee or Committees to deal with the numerous *ad hoc* problems which will arise in offshore and Arctic oil developments and demand quick, concerted and consistent management-implementation decisions by various government administrative departments.

The experienced administrator will note that in the foregoing we have left unconsidered the problem of formation of a centralized program for marine science and technology on which a single budget could be framed. This would certainly be a necessity if one were, for example, to consider marine activity as an end in itself, which must be balanced against competing sources of funds. However, this could be the case at present only if we were to consider a single budget for all science, of which this field is a competing part. It is our view that the components of marine science and technological activity can really be judged only in relation to their relevance to the national goals reflected in departmental policies, not balanced off against other scientific activities. At the present time, what is needed is information on how the marine science and technological activity may effect national objectives, the setting of priorities to accomplish them, and the assignment of these priorities to appropriate departments. This could be accomplished by the Cabinet using advice derived from the National Board on Marine Activity. With such guidance, individual departments can develop sustainable programs and budget them for joint implementation through the CCO.

What may be asked is, "How much is being spent on marine science programs?" This, however, is a different question. The Treasury Board should be able to provide such information, or could enlist the aid of the CCO secretariat to prepare it. The information is certain to be useful as reference to both the policy recommendation and policy-implementing bodies.

To continue with the subject of policy formation, we wish to draw attention once more to the fact that marine science and technology must be regarded as part of environmental science. One of the most important responsibilities of government is to develop a means to monitor, and if possible control, the effects of our activities on our environment. The seas are not only a major component in the interacting system, but may provide some of the best measures of this impact. This will become more and more evident as we develop our knowledge of regions of the country as interacting ecosystems, rather than simply as political units.

There is a need for a body, independent of government, which gathers together experts from all fields to assess the adequacy of our knowledge and the effectiveness of our laws for the control of environmental quality. We support the conclusion of earlier Study Groups of the Science Council that the present situation is already serious enough to warrant the formation of a special Environmental Council of Canada, analogous with the Economic, Science and Canada Councils. We would add to this, that the importance of the marine environment is so great that there should be a standing committee of the Environmental Council, constituting a review committee on conditions in the marine environment and the position of our marine science and technology programs relative to it. This committee should be made up of individuals who are distinguished for their knowledge of marine environmental problems and man's influence on them. Because of the great common interest we share in the Arctic, we believe it would be especially appropriate to invite to this committee, in addition to distinguished Canadians, at least one distinguished individual from each of our giant neighbours, the U.S.A. and the U.S.S.R. On our diagram (Fig. VI.1) this independent review committee is shown on the right-hand side.

The foregoing has been all about improving the process of policy formation and the implementation of the "in-house" government programs. This is important and must be carefully considered if we are not to bog down with indecision, or find that all priorities in our marine science and technology programs become set by the ambitions of particular departments. However, the most important problem has not been discussed. What we regard as our most important suggestion for organization development is reflected in the chart on the right side of the central panel. It is the Canadian Ocean Development Corporation, which is of sufficient importance to command the next section by itself.

Technology Transfer and the Development Agency Concept

The primary objective of investment by governments in marine science and technology is enhancement of the use of the environment and of the production of marine resources. In Canada this has traditionally involved promoting the productivity of industry and serving the needs of government departments in the fields of fisheries, defence and transport. At the present time, the rapidly developing interests in oil and gas extraction, recreation, anti-pollution and climate control give promise of dwarfing these traditional activities in their requirements for service based on both scientific and technological advances. The demands are especially heavy in the area of marine technology, which even more than marine science is entering a rapid growth phase.[1]

Much of the present marine industrial activity is new and may be expected to undergo continued rapid change. At such a time no country can afford to be complacent about the effectiveness of its institutions for making commercial use of its marine science and technology.

The problems which have to be resolved to promote an expansion of marine industrial activity can be seen clearly only if they are viewed in the light of criteria for a successful development program. Clearly, the first objective of such a program is *to create new industry based on the opportunities exposed by the past and the current scientific and technological work*. This requires that efforts be made to promote a type of operational-level contact which will lead to information exchange among the government- and university-supported research and development (R & D) and the industry which has the manufacturing and marketing skills. However, other things being equal, dependence on "technology-transfer" alone can be expected to lead to a growth rate which is only roughly proportional to the size of the government-sponsored R & D program. Such an industrial growth rate is not sufficient in this new area of marine technology and associated industry, which is in the early phases of a typical growth curve. In this phase, knowledge growth tends to be very rapid. The challenge lies in translating scientific potential into industrial actuality. To achieve this level of industrial growth, it is clear that a rather different approach to the problem is required.

What is required is that new industry generated by government-sponsored R & D must itself become capable of creating or generating new lines of products or services. That is, the national R & D program should be regarded as consisting of two parts: there will be a government-sponsored R & D program which provides a continuous base line of high-quality research and technology in the basic and applied fields, and from which both industry and government applications can be expected; there is a second R & D program which is specifically oriented and which provides a particular focal point for new industrial growth from within the industry. While this latter program might be carried out in a variety of ways, it is probably simplest to regard it as a separate industrially operated R & D program.[2]

[1]Bascom, Willard. Technology and the ocean. Sci. Amer. 221 (3): 199–217. 1969.

[2]This concept is alluded to by the Chairman, Privy Council Committee on Scientific and Industrial Research in the Confrontation Meeting of OECD. (OECD Reviews of National Science Policy, Canada, Paris, 1969.) As he pointed out, it is probably more effective to initiate new research projects in private industry laboratories than to attempt to transfer work in progress from government to industrial laboratories. Both are obviously needed.

In this report we have expressed the view that there is a real increasing world demand for oceanography. Developments which are already being promoted in Canada will place heavy new demands on marine science and technology for information needed in government departmental obligations to provide service and to exercise control for the common good. But it would seem naive of us, as authors of this report, to recommend any substantial increases in the level of government support of marine scientific and technological activity, unless this policy were consistent with an industrial expansion policy designed to ensure that it gave reasonable returns to the Canadian taxpayer who supports it. There are several features of the Canadian situation which pose special difficulties in the way of achieving a satisfactory rate of industrial expansion.

Perhaps the outstanding feature of Canada which confronts the marine developer is that the major Canadian financial and industrial enterprises are concentrated, along with over 60 per cent of the general population, inland along the drainage basin of the St. Lawrence River and Great Lakes. Thus the major control segment of the Canadian economy has little real knowledge or experience of the coastal or marine environment. Even more important, it has been slow to appreciate the opportunities. The situation is very different in our industrially vigorous southern neighbour, where nearly half of the much larger U.S. population lives on the coast[1] in major urbanized and industrialized centres. Furthermore, the continental shelf of mainland U.S.A. and Alaska is only about 75 per cent of that off the Canadian coastline, with the larger part of the U.S. shelf off the coasts of Alaska. Since the economies of the United States and Canada are closely integrated, it is natural to expect that U.S. commercial interest in the Canadian shelves, especially the more accessible southern parts of them, should be high. It appears to be generally higher than is the interest of most Canadians. Special efforts seem to be indicated to enable the Canadian financial and business community to judge the relative merits of opportunities in the marine environment.

A second factor of particular significance to the growth of new marine enterprises in Canada is the high degree of foreign, especially U.S., ownership of business in Canada.[1] It is natural that the foreign-trained, company-oriented management of such firms will look to already developed and familiar sources for supplies and for services of operations. Most of these will be in the home country. Where such supply and support service industries do not already exist, it is also natural that foreign-owned industries tend to encourage their development in the familiar circumstances of the home environment, where they can be meshed intimately with existing networks or subsidiaries and subcontractors. In addition, while it has often been argued that foreign-owned industry does as much research and development in Canada as does Canadian-owned industry, there is every indication that research and development is managed by foreign-owned industries in precisely the same way that a Canadian-owned company does it; that is, R & D is centralized and, as far as possible, is associated with familiar and vigorous research, development and industrial centres, often in close association with university or government laboratories. Where a Canadian subsidiary is a relatively smaller and a more recent offshoot of a foreign parent, very special incentives would have to be offered to

[1]The U.S. Report of the Commission on Marine Science, Engineering and Resources refers to them as living in "coastal counties".

[1]According to DBS statistics for 1967, foreign subsidiaries had 26 per cent of the assets and about 40 per cent of the profits of all corporations in Canada. This share has been increasing; it was only 24.5 per cent of profits in 1964. The latest figures show that foreign owners control 60 per cent of mining, 56.7 per cent of manufacturing, 83 per cent of the chemical industry and 99 per cent of petroleum and coal products industries. (Ref. Financial Times of Canada, 58 (38).1. for Feb. 9/70).

induce it to develop an R & D program in Canada.

The subsidiary exists for the purpose of obtaining some saleable resource, such as oil or mineral ores, or for sales of goods in the Canadian market. Thus, in most cases, the foreign-owned Canadian subsidiary will depend on the parent company for most of its R & D. To generalize, design capability seems to rest with the parent firm, while the R & D that takes place in the subsidiary operation is usually concerned with the transfer of the technology itself. Incremental inflows of new foreign technology may be regarded as an advantageous supplement to an already well-developed Canadian marine industrial research and technology base. However, no such strong base yet exists in Canada, and it is clear that the technology which enters Canada as part of the much heralded "technological transfer" is not the type of technology that will sustain high levels of growth.

A third important feature of the Canadian situation is that our present population is so small, compared with our very large potential resources, that the satisfaction of our direct consumption needs is generally a very small proportion of the total demand for the resources put into commercial production. Purchasers of Canadian resources are therefore most interested in development of a foreign major market. In the case of U.S. firms, this is mostly in their home economy. These purchasers cannot be expected to be especially concerned with the impact of their operations on the Canadian economy. Technological developments and innovations in the host country which increase the efficiency, safety, or ease with which the material is made available, or which increase the company's sales opportunity or its overall profit, will be encouraged by such industry. Developments which promote the economic or technological independence of the host country (Canada) are unlikely to be encouraged, and developments which might eventually lead to an improvement in the competitive position of the host country in accessible markets are likely to be actively discouraged. Without prejudice to the free flow of information on which scientific advance depends, *this aspect of the Canadian scene tends to reinforce the case for a special effort to encourage an independent Canadian technological capacity if strong indigenous growth is to be achieved in this new industry.*

Finally, in the present day of easy international flows of capital, the advent of large and foreign-owned multinational corporations may place extra difficulties in the way of rapid and well-balanced marine industrial growth in Canada. A successful small Canadian business, which is developed by individual initiative and private means, will usually find a need to expand. This will require the injection of new capital. Our interviews with fledgling entrepreneurs in Canadian marine-oriented industry have repeatedly emphasized the many difficulties faced by the company which proposes to do this. Most Canadian private loan sources tend to be unfamiliar with the marine field and in any case have a reputation for conservatism. It is claimed that this applies *a fortiori* to federal government administered or backed loan schemes, which are too sensitive to possible public criticism to risk underwriting a business which might fail. The alternative of risk investment capital is available in some areas. In the marine field it is largely foreign. If the investor is a large foreign-owned company, access to such capital is generally in exchange for control of the company. Such an exchange obviously has important implications for its long-term development. Ironically, there are many reasons why "selling-out" is accepted and, in some cases, desired by the original company. What is of importance, however, is that the result seems usually to involve "consolidation" of total company operations with subsequent export of the sometimes precariously nurtured, but now experienced and successful, Canadian technological and management expertise. *It is just this expertise which is required for the successful development program.*[1]

These features of the Canadian scene are the subject of current public debate among those with better general knowledge of the problems and conditions than is possessed by the authors of this report. There are no separate inventory statistics for the marine-oriented Canadian industry, so that it is not possible to develop illustrative material representative of the marine sector which would give a better appreciation of effects on our past development than can this general debate. Its special relevance to this report arises from the judgement that the marine field is at the very beginning of a vigorous growth phase. Policy at this juncture can, therefore, have an especially profound effect on its future general health and profitability. Considering the present Canadian industrial situation, it is our belief that the development of a marine industry from which Canadians could derive full benefit will *not develop by itself*; explicit action by government is required. This conclusion must be juxtaposed to our earlier conclusion that opportunities for marine development in Canada appear to be exceptionally large, especially in association with marine activities surrounding offshore oil and gas production. Opportunities in fisheries, transport and recreation are not by any means negligible. A third consideration, perhaps as important as any, is that marine activity represents an area of future world economic and social development in which Canada is not significantly behind other nations, if for no other reason than that world developments are only just beginning! Canada has, in fact, a distinct advantage in having built a sound scientific background, a good base of research ship and laboratory facilities, and in having first-class educational facilities associated with them. If we have the will to make proper use of them, there is every reason for the marine field to develop into an industry which is of major benefit to Canada.

With this in mind, we believe that it is to Canada's overall advantage to embark on a deliberate policy to use marine science and technology for the purpose of expansion of the marine-oriented secondary industry. There are a number of measures which would seem to be capable of initiating this development program despite our peculiar present position. Steps to overcome the technology-transfer problem in "real-time" (i.e. while things are happening, not months later) have been mentioned earlier. So too has the creation of industrial technology by providing some minimal government markets through "contracting out". We deal with this problem in more detail in the next section. In addition to these, however, there are several measures which require sustained attention and control. Loans and other encouragement of R & D in Canada by both Canadian and foreign-owned firms should be encouraged where it can be assured that the outcome will mean maximum growth in Canada. Industry dependent on foreign R & D must be considered as of relatively little interest in the context of our present discussion. Foreign industry which is attracted by Canadian cost-sharing programs in R & D should be encouraged only where the Canadian subsidiary can demonstrate operational independence and a competence which would permit it to develop and market new lines resulting from the research. Sales of new companies to foreign interests, which result in the loss of R & D or management expertise

[1]This fact is underlined by recent legislation before the U.S. Congress to permit Canadian immigration on a "preference" basis (*Globe & Mail*, Jan. 23/70) apparently in response to the desire of U.S. multinational firms to have flexibility in movement of executives of Canadian subsidiaries. Emigration of Canadian technical, scientific and management manpower was drastically reduced when U.S. immigration quotas were imposed about a year ago. Canada for many years had a similar policy which selectively encouraged immigration of skilled and professional personnel.

and therefore conflict with the growth policy objectives, need to be guarded against. But most important of all, in the present day of great technological complexity of marine operations, and in the presence of very large foreign-controlled multinational corporations, many involving foreign government participation, it is essential that Canada take steps to set up a "systems manager" to ensure a balanced development of the many different production and service industries required for economic production of our marine resources. With the wide responsibilities that such a systems manager must have, and with the necessity of ensuring consistency of marine operations with national objectives and policies, it is clear that government cannot rely on private industry to assume the active role as manager. Problems of this sort are not unique to Canada. Similar situations and problems have arisen before in other countries. It is the practice for example in France, Britain and in Sweden for the government to play a very active part in organizations designed to meet such needs. Even in the free enterprise atmosphere of the United States, the National Aeronautics and Space Agency (NASA) has been formed as a means of implementing government policy in a complex area and marshalling the complicated array of industrial components necessary for the task. In our view, the problems faced by the Canadian government in developing offshore resources for the benefit of Canadians are comparable. This, and most of the other conditions outlined above, point to the need for government to set up a Canadian Ocean Development Corporation with major management and financial responsibilities.

The Canadian Ocean Development Corporation (CODevCo)

The requirement is for a centralized industrial-type organization wholly under Canadian control which could quickly undertake to carry out marine development and innovation projects for which existing government departments or agencies are not well suited, and to actively engage in the marketing of the products and services produced.

The terms of reference for this organization should be to accelerate Canadian industry's capability and capacity to produce those goods and services considered to be in the national interest, with a special eye to domestic and international markets. To do this the organization must be fully aware of top-level government policy in this industrial sector. It must then be able to act as a systems manager, to study the entire complex of machines and services needed to perform industrial tasks, or needed to enable government and industry to manage them. It should decide which components need development, or could with national advantage be manufactured and marketed from Canada. It should then be in a position to proceed to contract with industry to work on the designated components.

Where suitable companies for carrying out designated tasks do not exist, it should be able to encourage their formation. For example, it should provide funds to a firm which would enable it to gain rapidly the necessary marine design experience. This could take the form of a contract between a Canadian company and an experienced foreign firm, specifically to supply a design team with the intent of technology-transfer for specific equipment such as drill rigs and pipe-laying barges. The contract should leave an independent Canadian capacity. Alternatively the Corporation could even consider the purchase of foreign subsidiaries which have valuable expertise. The present system of permitting a foreign firm to set up a dummy subsidiary in Canada does not support continued Canadian growth and usually means a restriction of the subsidiary's possible markets. This should not be tolerated except in exchange for very advantageous economic reasons other than the company "presence".

Private Canadian companies are anxious to enter the field of marine technology. They are deterred by lack of knowledge and know-how, as well as risk capital. While the Development Corporation must consider market demand, to a large extent it will be attempting to anticipate that market. Many of the items will have high unit costs ($10 million to $25 million). The Corporation must be enabled to enter into projects with high development costs with a high risk. This high risk may include being too early for the market. It may include higher costs because the equipment can be duplicated at lower costs by foreign companies which initially had higher technical competence and experienced organization and subcontractors. It will sometimes mean that another country develops a "better mouse-trap" in the interim. While the company will probably not take unreasonable risks, it must be strong enough to resist the criticisms it will certainly get, so long as it remains fully aware of its task of promoting Canadian industrial expertise and capacity within the framework of national policy. Indeed, it should be recognized from the start that if *none* of its projects fail, the Corporation is not being sufficiently venturesome.

To accomplish its mission CODEVCO must be wholly Canadian controlled, must have a large measure of financial stability and independence of operation within broad policy guidance, and must be vitally industry-oriented in its own policy making, managing and operating. While it must be able to accept special assignments from government, it must be free to operate them in its own way according to its character, as a full and responsible member of the business community. *It must be able to make a profit itself, but its success of operation must also be judged on the profitability and rate of growth of its associated contractors.*

Under our government system, the requirements and tasks of this Corporation mean that it must be set up as a Crown Corporation with as much independence as has the Polymer Corporation or Air Canada. It should have a Board of Directors drawn from the Canadian community. Because it must be fully familiar with government policy and government operations, especially government R & D programs, we suggest that it have a Board consisting of seven members. Initially there might be three from top-management level of government, three from industry, and one from university. This distribution is rather more heavily weighted toward government than is really desirable, but we recognize that in the formative years, familiarity with the workings of government will be essential. At the end of an initial three-year period, one of the government members may be replaced by an additional industry member. The president of the Corporation must be a member of the Board and should probably be drawn from industry. The chairman of the Board could be from either government or industry so long as he has wide practical experience and top-management skills. The university representative might properly be a Dean of Engineering.

As a publicly owned corporation, CODEVCO must have a voice in Parliament through which it can report its operations and explain its operating principles. This channel should most appropriately be through the Minister of Industry, Trade and Commerce. We have so shown it on Figure VI.1. It can also offer advice on overall policy as a result of its business activities. One of the members of the Board should always be on the National Board on Marine Activity. In its operations it must, as any modern industry, maintain some R & D activity, either through underwriting it itself or by encouraging the use of other government industrial assistance programs such as PAIT. The research and development operations must be closely co-ordinated with those of the government departments, and to this end the president of the Corporation should be a full member of the CCO. However, it will need expertise of its own to provide liaison among industries and with government "in-house" R & D to stimulate creation of consultant groups, to develop scientific data centres for industry, etc. We do not intend to limit the flexibility of the Corporation by specifying its structure. However, it has such importance that we regard it is worthwhile to examine some of its possible functions and structures in order to arrive at an estimate of its requirements for staff and financing. For example, the side of the operation which is science dominated might be under the charge of a Vice-President-Science. A similar situation applies to the engineering side of the business. Its functions include funding for new designs, equipment and techniques, market analyses, etc. This side would require engineering training and experience and calls for a Vice-President-Technology. It seems clear that the company would require a policy co-ordinating directorate which could make overviews of Canadian and foreign activities, maintain inventories of policies and action, look after the public relations of the company, and make known to industries and the public the policies and guidelines of the Canadian Government that affect company planning. Also the company will need to be able to set up task forces for many of its special missions. It must be able to appoint the most appropriate individuals to these task forces from wherever they can be found in government departments, universities and industry. It must be able to offer sufficient incentives to both individuals and their employers so that fullest possible staff mobility is assured. One of the very important aspects of this activity is the resulting increase in communication within the whole community. A schematic diagram for a possible company organization is shown in Figure VI.2.

In order to have some concept of the size of CODEVCO, it has been necessary to study in detail some of the projects it could consider undertaking and to assess staff, operating and project costs. By reference to the foregoing chapters, we are able to identify about fifteen of these, and some details concerning components and costs are set out in Appendix B. We cannot hope to deal with these in any detail. However, some illustrations may be helpful.

One of the most important, and initially perhaps the largest, program which should be undertaken is clearly the underwater drilling program. This was described as "Drilling from the Bottom" in Chapter II. Since writing this proposal, we have learned that government committees in the United States and Japan have also concluded that such a system has high potential pay-off. An attempt to carry this out in Canada is clearly justified. If successfully completed, it will have great domestic application. The system has many components. If some are better developed elsewhere, we will have gained the technological capacity for Canadian manufacture under licence. If ours are better, we can sell. But the area will in any case yield economic benefits from investment in technology and know-how. A total investment of the order of $60 million over five years could conceivably give Canadian industry a monopoly in this one area. At the very least, we should come away with one third of the field and "know-how" for most of the rest. Many of the parts of the system will have wide applications.

Many kinds of work both on the sea and under it require rather large amounts of electrical power. Canada has both private and provincially owned agencies with advanced technological knowledge concerning power generation from different sources, and experience in long-distance power transmission. Problems of transmission and running of equipment underwater demand much more study. Underwater *in situ* generation

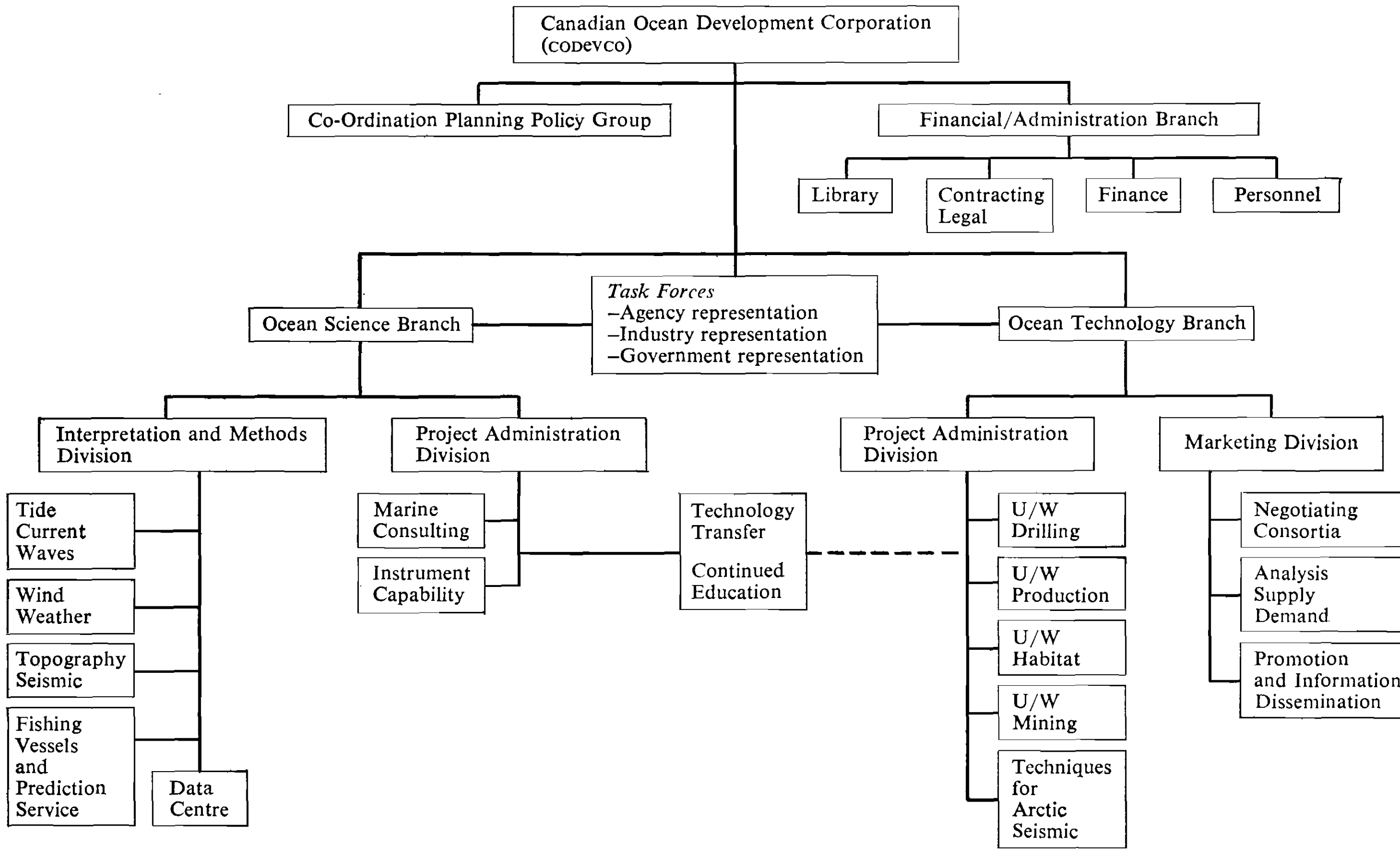


Figure VI.2–Schematic diagram for possible organization of a Canadian Ocean Development Corporation

Table VI.1–Canadian Ocean Development Corporation, Estimated Staff and Annual Expenditures

Operating Divisions	Staff (full time)			Operating Expenditures	Project Expenditures	Total Annual Expenditures
	Prof.[a]	Tech. Support[b]	Other[c]			
		man-years			$000	
1. Interpretation and Methods	13	8	9	430	2 200	2 600
2. Project Administration	19	11	12	650	37 000	37 600
3. Marketing	10	4	8	340	100	400
4. Planning and Information	5	5	6	270	1 200	1 500
5. Finance and Administration	9	15	10	530	300	800
Subtotal	**56**	**43**	**45**			
Totals	**144 man-years**			**$2 220**	**$40 800**	**$42 900**

[a]Professional category–includes scientists, engineers, along with some legal and financial experts.
[b]Technical support category–includes data collators, computer programmers, draughtsmen, etc.
[c]Other category–includes secretaries, clerks, and maintenance personnel.

is a decided possibility with especially large possible application. It may prove to be an imperative for the underwater drilling program.

If the oil industry develops from a Canadian base, using Canadian labour, there will be a continuing requirement for efficient crews and ships. There is now a substantial Canadian offshore fishing fleet and a much larger offshore world fishing fleet, both of which are ceasing to be labour intensive. The advent of oil will accelerate this process and compete with fisheries for ships. It is in Canada's interest to develop the automation of fishing vessels with an eye to reducing crews from the present 12 to 14 men to less than half that number. Success here would open a market in Western Europe and possibly in Japan as well. In the case of Japan, it might be possible to trade fishing and oil technologies.

At a number of places in this report, we have drawn attention to the need for environmental prediction services, especially for the offshore and Arctic oil industries, but in other cases as well. At present this area in Canada is almost totally an "in-house" government responsibility. But it cannot be emphasized too much that the present government staff is quite insufficient for coping with the new demands. The Development Corporation would be an ideal mechanism through which government could effect the setting up of privately owned Canadian industrial prediction and interpretation services with access to present Canadian information networks and ability to make use of them without detracting from the public service.

In addition to the review of projects, an analysis of the manpower and operations of the Corporation itself has been carried out for us by the Department of Industry, Trade and Commerce. It is based on the projects discussed above and the project areas layed out in Figure VI.2. A summary of the results is presented in Table VI.1.

We cannot pretend to have expert knowledge of the problems or projects which we have outlined, although we acknowledge and are extremely grateful for the outside help we received from two major companies and a government department in preparing the estimates. Almost everyone who looks at them suggests raising some and reducing others. The overall changes are such as to suggest that a Canadian Ocean Development Corporation with an initial capitalization of between $40 and $45 million per year for a period of approximately five years should be able to exert a considerable impact on the secondary industry associated with marine activities. At the end of this period, the effects of the Corporation should be clear and a review of its operations by Cabinet might suggest a change in the government input: reduction, increase, or even extension to other than marine areas. The Corporation should however, have a minimum charter period of ten years and some minimum assurance of the level of support in the second five-year period.

In the section on oil developmental requirements in the Arctic (Chapter II), we have displayed a simple calculation of the present worth of investment by the government in terms of returns to the government in the form of tax revenues alone. By using estimates in connection only with the oil extraction from the Arctic, and by ensuring that at every step our calculations were considerably more conservative than the best written and verbal advice we could get, it was concluded that one could anticipate a return in federal tax revenue amounting to $40 million per year starting in about ten years time. Even at 8 per cent, the present value of this revenue is $230 million. This estimate was based on an effort sufficient to ensure 5 per cent more participation in the secondary supply, construction, equipment and service industry associated with oil production, than would occur without government action. It is not concerned with oil sales. We wish to point out here that as the Canadian Ocean Development Corporation is conceived above, it would operate in many areas in addition to the Arctic. It should generate a far greater than 5 per cent increase of Canadian participation in the oil industry, and will have a major impact on development of other industry and on exports or sales and service. It would seem that the proposal we make here for the investment of approximately $225 million over a five-year period, and probably of the order of $200 million in a further five-year period, should be a good investment simply on the basis of direct tax revenue returns. Similar benefits would accrue to the provincial and municipal governments and to the public generally.

Administrative Mechanisms in Science and Technology

During this study we have on a number of occasions become concerned with the adequacy of present administrative mechanisms for achieving maximum use of marine science and technology in the expansion of industrial activity and for increased effectiveness of government management. There are a number of situations where the government's own administrative regulations seem to prevent it from doing the things it wishes to do. In this section we attempt to consolidate and develop a number of suggestions, some of which have been referred to in earlier chapters.

We have already pointed out the necessity of recognizing that the relations between individuals in an administrative hierarchy and between individuals in different hierarchies must be viewed as a series of buy-sell transactions. The motives of the two parties in any commercial transaction are different; it takes place when both are satisfied for different reasons. A number of commonly accepted rules are essential to the development of the commerce. Where the transactions seem to have no special value, or at least are of no apparent immediate advantage to either of the parties, minor routine transactions may be guided by rules. However, when the motives of the two parties are very different and the advantages apparently one-sided, the disadvantaged party is certain to work to circumvent the rules. The greater the divergence, the more difficult it becomes to enforce rules. The usual means to overcome this problem is to provide incentives for the formerly reluctant participant. In our view, there is a need for much greater and more general use of incentives in the commerce of administration of marine science and technology if it is to achieve the goals which the nation has for it.

Administration of Basic Research and Training

Within the university, the administration makes very little attempt to determine the research program of the faculty, although in the usual way there are salary incentives for those who can demonstrate their excellence or marketability in various ways. The nature of university research is largely determined by the ability of the research worker to obtain grants. In marine science and technology in Canada, most of the grant monies come from the National Research Council. This organization is the only one in Canada empowered to make grants solely on the basis of a judgement of the standard of scientific excellence of the research proposal and its sponsor. There seems to be little doubt that this function must be jealously guarded. However, at the present time, grants of this sort are confined solely to university staff and are administered by the university. In earlier pages of this report, we have referred to the importance of having at least a few top-quality scientists and engineers within individual government departmental laboratories, whether or not their immediate researches can be shown to have direct relevance to the mission of the laboratory. A similar argument could be applied to scientists in industrial research laboratories. If the most important purpose of the NRC grant is to maintain a high level of excellence of science in the country, it must surely include all the best scientists, whether or not they are in the university environment. This logic implies that the National Research Council must take some responsibility for the encouragement and support of high-quality research in both government departments and in industry. In fact, to exclude the work of a large fraction of top scientists from judgement and support on the basis of the merit of their work relative to the general level of excellence in the country is to deny a principal aim of the granting system.

The present situation appears to have arisen from the notion that the government and industry laboratories are assigned their own sources of support and that the general level of each should be controlled. There seems also to be some concern about the possibility of unjustified "double funding" of projects. It is clear that the number of grants for excellence, which should be made available to government and industry laboratories, must be kept at a level which will not interfere with the pursuit of the laboratory objectives. Because of this, any applications and acceptances of science grants by their workers would have to be subject to approval of the laboratory director. But the secondary reasons for confining NRC granting to the universities staff, which appear to be based on the administrative convenience of avoiding competition between science in government, university and industry, appear to us to be without sound foundation. Fears that such competition may detract from funds available to universities may be ill-founded anyway, but if they do, this would seem only to reinforce our doubts as to the efficiency of the present system. What is required is to balance the opportunity for a "fair" share of available funding. To meet this requirement, fuller use must be made of research funding *by using criteria other than simply excellence*. This point is returned to below.

A number of government scientists have established reputations and have abilities which make them valuable assets to the universities. A small proportion of these have formal (but honorary) university appointments which qualify them for graduate instruction. As industrial research grows, such cross-appointments are likely to develop in this group as well. It would seem especially appropriate that those government and industry scientists with university appointments should be enabled to make application for NRC support of research projects which are designated as graduate students' projects. These should be supported on the same basis as are graduate activities supervised by other university staff. The number and quality of such appointees must, of course, be carefully controlled by the university, which must remain responsible for the salaries of most of its staff. Research accounts for these students should be handled by the university in the usual way.

Scientific excellence alone is not the only criterion for supporting scientific activity. A large proportion of the effort must be judged and supported on the basis of its direct relevance to national purposes. At the moment, since by far the greater proportion of university research support comes from the National Research Council, the responsibility for this judgement, with respect to university research, also falls on its shoulders. It is, of course, most difficult to weigh the relative merits of a proposal for research in the chemistry of an enzyme against that of a proposal to study energy exchanges at the air-water interface. Hence, in any granting system, certain decisions as to the division of grant moneys among various major fields will require judgements of national relevance. But except at this level, we strongly question the wisdom of a system which permits a judgement of relevance of an individual research proposal to be made *by the same group of examiners* as is charged with judging scientific excellence. In our view it would be far preferable to have judgements of relevance done at the level of operating government departments. For this purpose, we believe that there should be substantial increases in the granting and research contracting money dispensed by the research arms of government departments, and that university and government research staff should be able to apply for them in the usual way. Of course, the concepts of excellence and relevance are not mutually exclusive. However, we contend that excellent research should be supported–by the National Research Council–even if its relevance is not immediately apparent. On the other hand, there may be occasions when rather pedestrian research is of great relevance. It also should be supported–by an appropriate mission-oriented department.

The concern of the government administrators that a research project should not receive funding from more than one federal government source needs to be most carefully reconsidered. It seems clear that no one project should receive double funding from the same ultimate source on its merits as high-quality research. A concomitant of this is that the single funding on the basis of excellence must be adequate to support that research. However, the criterion of relevance presents a completely different situation. It is more than likely, in an interdisciplinary area such as marine science, that a particular project or group of projects will be of interest to a number of departments although no one of them may be prepared to underwrite the total cost. In fact, this is the usual situation with many projects dealt with by the Canadian Committee on Oceanography. In this case it is important to recognize that a particular relevant project should be eligible for support from various sources. Funding may be accomplished through applications to several departments, provided the project leader recognizes his responsibility to make full disclosure of past and projected sources of support in his submissions.

The problem of tying university research too closely to the production of graduate students has been dealt with in detail in Chapter V. To solve this problem, attention should be given to increased use of postdoctoral fellowships and of inclusion of technician support in NRC and government grants and contracts to university staff or staff groups.

Earlier in this report we have discussed the problem of fluctuations in the supply of recruits to marine science and technology. It is clearly one of the most difficult areas facing the administration of graduate training. In effect, our past fluctuations in the supply of university graduates have been left to look after themselves, largely through losses of surplus production to the United States and recruitment at times of shortage from worldwide sources. The ability of university, government and industry to recruit the best-qualified professionals which can be attracted from a world supply is a most valuable asset to scientific, and especially technological, development in Canada and should not be restricted in any way. However, this does not obviate the need to smooth out the fluctuations in recruits and to work towards the adjustment of the total rate of production to the demand.

It is quite likely that adoption of proposals made in this report for major oceanographic projects would help to alleviate problems of supply-demand fluctuations, simply through enunciation of a longer term policy which will create a steadier market. However, attempts must still be made through the development of modern planning, programming and budgeting methods to stabilize and make clearer the government demand, so that universities in particular will be better able to project this demand about five years ahead. But there will still be a need for buffers against imperfections in the system. We therefore urge that the National Research Council take the initiative in this area and, in concert with government research departments, institute a flexible system in terms of both numbers and duration of postdoctoral fellowships. The aim of such a system is to create a realistic inverse relationship of postdoctoral opportunities to the short-term level of scientific recruitment in government laboratories. To implement this will probably require a recognition by Treasury Board and the Minister responsible for Science Policy that granting agencies must retain a degree of flexibility in the transfer of funds between scholarships and the direct support of research operations.

Finally, it is important to recognize that certain areas, such as the support of industrial R & D and the training of engineers and technologists, will require special consideration, probably throughout the 1970s and possibly longer.

It seems likely to us that, if much of the R & D expansion which government has attempted to encourage through various incentive schemes were in the marine science and technology area and administered through the Canadian Ocean Development Corporation, some of the past difficulties referred to in Chapter V would certainly be overcome.

The training of marine engineers and technologists and eventually, one hopes, of environmental engineers, is a new area for Canada. There is clear indication that the Institutes of Oceanography at the University of British Columbia and at Dalhousie are prepared to undertake this training at the graduate engineering level in conjunction with local university departments of engineering. They will require special NRC support for this purpose. There are other universities which also aspire to development in this marine area. While the authors do not have information on which to base a judgement of the present relative abilities of engineering schools, we subscribe to the general concept, developed by the National Research Council and followed in the marine science and technology area, that Canada is best served by the concentration of the greater part of our support in a few centres of excellence. We believe there are decided advantages in utilizing facilities of the main oceanographic centres and the staff of the existing institutes in extending our training into the technological sphere.

Training in marine specialties at the undergraduate level has to be looked at differently. Our requirement is for good engineers first, then specialists. At this period of our development, we do not believe that the specialties are clearly enough defined to warrant any dilution or redirection into marine engineering at the undergraduate level. This has been attempted at various U.S. universities, and it is our impression that graduates of such schemes were at a disadvantage when a large U.S. oceanographic program failed to develop. However, many more marine examples could well be used in the course of the training, for example, of a mechanical engineer. The Study Group was much impressed by the plans of the Dean of Engineering at Memorial University of Newfoundland to take advantage of his natural environment to do just this. We believe this to be sound practice which would not place his graduates at a disadvantage. Quite the reverse. Such aspirations are to be encouraged.

Development in marine research and industrial activity will certainly make increased demands on the products of the various provincial institutes of technology. It does not seem too early for these institutes to consult with potential industry and government employers with a view to the introduction of technical courses directed to a greater understanding of marine problems. If marine activity develops very rapidly, these institutes may require special financial assistance.

Special Problems in Government and Industry–Administration of Research and Development

The types of activities in which both industry and government engage may be broadly classed as either service or science. Service is a normal and principal function of both. Once a goal has been defined, an organization for implementing it can be set up. There is then a proper exercise of authority from the top, ensuring a satisfactory standard of performance at the operating level. The feedback, by which authority judges the effectiveness of the service and makes necessary redefinition of functions or adjustments of output, comes in various ways, ultimately from responses of the consumer public or the voter. While the operations are complex in detail, the general requirements for operating the system are relatively well known, and both industry and government have evolved similar and relatively effective administrative techniques for dealing with them.

The nature of research is quite different. If the concepts it uses and the problems it examines were as clearly defined as they are in the purely service area, there would be relatively little need for it either in government or in industry. They could concentrate their support on development, engineering and innovation fields. But it is the rule rather than the exception that research reveals a new way of looking at a problem, or the need and possibility of a new approach to an established process or product. Research is thus needed in order to have a flow of useful information from the level of the individual scientist or team of scientists to the top authority which can ensure its incorporation in the service area. The organizational structure in the science side exists primarily for the purpose of promoting this information flow. Authoritarian governmental and industrial administrative systems are not at all well suited to this purpose. In fact, we have suggested earlier that the effective operation of research necessitates a surrender of control over the operational research level in exchange for its sometimes small, but frequently crucial, contribution to the functioning of the community as a whole.

While there are some substantial differences in the way government and industry can use scientific research, they share the characteristic that, while recognizing the scientist's need for independence of action, the *field* or research activity must be planned and integrated into the entire effort. The best examples of this are to be found in industries, and it appears that government still has much to learn from them. As Kinzel (*op. cit.*) points out in connection with industry:

"One of the mistakes that was made early in the century and quickly corrected was to consider research a side effort, requiring contact only when something promising had been developed. Today it is generally recognized that to get the most out of research and to give the most to it, the person in charge of research should not only be in contact with top management but should be a member of the top management team sitting with them regularly, to understand the nature and the requirements of the business."

Because government operations are elaborate, this kind of integration is difficult. However, steps towards it must be developed. It is not a satisfactory substitute to have *former* scientists *as* top management. If their field is at all active, their technical knowledge is quickly outdated and their scientific evaluations are not appreciably better than those of the intelligent layman. They are in a position neither to select areas, processes or products which are suitable as research projects, nor to determine how they should be carried out. Such decisions must be made by the research director who is thoroughly familiar with the nature and requirements of the field. It is the business of top administration alone to consider the implications of research and to decide the extent to which to call for modification of engineering and management aspects of the business. In this area former scientists as top management are an asset.

This particular buy-sell transaction has posed special difficulties for government administrators, and the means for overcoming them are not well understood by either of the participants. The situation in Canada is certainly not worse than in other parts of the world, and in the marine field, scientific performance suggests that it may have been appreciably better. However, there are still particular problems which have come to our attention and for which solutions need to be sought.

In the specifically scientific aspect of the work, it appears that the government administrator's desire for detailed manipulation of the system in the interests of orderliness, homogeneity and efficiency of control may be creating stumbling blocks for research. For example, government has set up a member of its departments, some of which have operating responsibilities in the public sphere, as service agencies for other government departments. Thus the Department of Public Works has been assigned the responsibility of servicing the construction and real estate needs of other government departments (except for the Defence Department, which is served by Defence Construction Ltd.). The Department of Supply and Services acts as the purchaser for other departments, including the negotiation of R & D contracts between departments and outside agencies. The Public Service Commission and the Bureau of Classification Revision are final authorities in the hiring and salary rating of all government staff. These service areas within government can provide valuable and essential services, primarily because there exist in them experts who have an up-to-date working knowledge of the market. They thus represent an excellent source of information and advice. However, government regulations have established them as monopolies within government, and the efficiency of this operation is not open to test in the market place. Unfortunately, the services they attempt to perform are not uniformly good, and in some cases create real difficulty. The source of this difficulty seems to lie in the fact that the operators are not themselves either familiar with or very interested in the users' requirements, and are not finally responsible to their users for a judgement as to the effectiveness of their service. The merit rating and salary level of a clerk in any one of them is determined within his own department.

In its recommendations on financial management, the Glassco Commission recognized a need for a closer linking of authority and management. This was to be accomplished by giving departments authority over their financial resources and making them accountable for disbursements, and by making them further responsible for designing and maintaining their own accounting systems. To judge from the complaints of the scientists, there has been a failure to carry this principle through to management of operational procedures, which results often in an inflexibility in personnel assignments, unrealistic delays in the provision of services, increases in costs, and a higher frequency of mistakes in orders. All of these impose penalties on the individual who attempts to do the best possible job. One might expect that in the more routine operations of government, these performance problems would eventually decrease in frequency and impact. Scientific operations are, however, by definition variable and the need for prompt action is often critical to their success. In the personnel field in particular, government administration must be aware that the *a priori* job assignment by central authority, which is appropriate for the service area, is inappropriate for research functions of both the scientist and his support staff. In general, no external agency can appreciate the day-to-day problems encountered by management. In the areas of employment of all research personnel, in the purchase of scientific equipment and services, and in the field of development contracts between government departmental laboratories and outside agencies, there is an urgent special need for these service departments to fully delegate their authority to the operational level of the laboratory. In the field of major development contracts at the level of government departments ($25 000 and over, say), there is a clear need for fully professional negotiations. In the marine science and technology area, it is hoped that in the future government will make use of the Canadian Ocean Development Corporation. Regulations concerning contractual arrangements should be framed in such a way as to make this possible.

The need which Kinzel expresses for integration of research direction with the general management of its organization reinforces an argument advanced above in connection with the concept of a Canadian Ocean Development Corporation. That is, effective research in government departments appears to depend upon having their research director fully familiar with his department's business and problems. While there is every reason to hope that these directors will at the same time become very knowledgeable about industry problems, it does not seem possible to expect them to be identified with and fully effective in serving the more specific and generally more immediate concerns of industry. There is no good substitute for encouraging industry to develop, as far as possible, its own research in close association with its development, engineering and marketing capability.

Since the exploitation of marine resources has a major impact on various aspects of the environment, there will continue to be a significant and undoubtedly growing demand for government research which the departments can apply in the exercise of management functions. This requires effective communications among research, management and development personnel. Unfortunately it appears that government has tended to stifle this by placing research and application in separate branches, often physically far removed from each other. In fisheries, the Fisheries Research Board is quite separate from the Resource and Industrial Development Services. In defence, the Defence Research Board is separate from the Technical Services Branch. The National Research Council operates a number of marine-oriented branches in Ottawa which appear to have little relation to the oceanographic centres or to marine-oriented industry. There are serious and obvious gaps in communication and often very different points of view between the research and development branches, which will not be resolved by rules, exhortations or telephone conversations.

We are sympathetic with the point of view that a considerable fraction of research must be protected from the temptation of managers to use their experts for day-to-day or short-term problems. We are also aware that the developers must not become too "subverted" by academic and long-term problems. There is thus a sound reason for separate organizational entities and budgets. But this does not at all mean that the operational units should not be housed together, nor that they should not be under a single laboratory director. In fact, since both have skills and knowledge useful to the other, this type of operating unit is highly desirable. The Halifax-Dartmouth complex provides many examples of interlocking operations, and we commend the present plans of the Department of Fisheries and Forestry to set up a joint FRB-Resource unit in the Bedford Institute to deal with pollution problems.

Irrespective of the separate need for a strong component of R & D in industry, in addition to that in government and university, there is a real and growing need to promote an effective exchange among these sectors. In the United States in particular, the use of university staff as industrial consultants is quite general, and Canadian marine scientists from both university and government have been used in this way by U.S. industry. Similar instances in Canadian industry are rare. In keeping with the interest of making the science and technology useful, this is a situation that must be radically changed. Here, however, we find a further example of the difficulty of satisfying both sides in the buy-sell transaction. On the one hand, we have government anxious to promote technology-transfer and, at least in some cases, industry which would be willing to use the knowledge if they knew enough about it. On the other hand, we have the research laboratory set up by government departments to carry out specified missions. If the laboratory is a vigorous one, it has far more research projects in view than it can undertake, and the laboratory director will always be on the lookout for staff which can both broaden and deepen appreciation of the R & D problems. If this director is now requested to promote development of an industry by welcoming its scientists and engineers into his laboratory to learn techniques or carry out programs unrelated to his mission, if he is told to contract out significant proportions of his research and development budget instead of building the competence of his own staff, or if he is asked to release his scientists for contract work of interest to the industry, he is clearly in a dilemma. The advantages of his positive response will seem very much one-sided on the other side, and most of his scientists will share his aversion to many such *ad hoc* assignments. He certainly cannot afford to lose them. While government administration could issue instructions to increase exchange of this kind, such instructions would necessarily be restrictive. Restriction tends to narrow the field of activity and produce a frustrating amount of red tape. The object is rather to broaden and increase the range of activity, especially in those areas where industry can develop a competence, and so increase Canadian industrial activity. It appears that some form of *incentives,* which would make industrial promotion clearly advantageous to the laboratory director, his scientists and his departmental administration, can be conceived and should be seriously considered.

In the case of placing industry scientists and technologists temporarily in government marine laboratories, there seems to be no reason why the visitor should not bring with him research funds which could provide for full operational support, including technical assistance, equipment, and the money needed to cover operating and extra laboratory overhead. Where the visitor is heavily dependent on the advice and assistance of a laboratory scientist, this could include compensatory support for this man's research operations as well. The grants for such work could well be administered from a special fund set up within the IRA program of the National Research Council or within CODEVCO, and may even include part of the salary of the industry worker as incentive to the industry. The term of appointment and the type of work should be a matter for mutual agreement of industry and government laboratory directors.

In the case of contracting out, incentives to the government laboratory could be provided rather simply, either by making special funds available to cover part of the costs of such contracts, or by premium increases in the budgets of laboratories which have successfully negotiated fully funded development contracts. It should also be possible for laboratories to obtain special preference status for Canadian industries with which they have developed an ability to communicate and carry out successful development projects. Such relationships are not easily established and initially often require considerable effort and patience on both sides.

To encourage the use of consultants, government administrative procedures must encourage laboratories to permit staff to act as private consultants. While government might well expect full reimbursement for use of its employee, it should leave open the terms of consultation to negotiation between the scientist and industry. Industry must judge his worth to it. At the same time, government administration should offer some type of premium to the laboratory budget, which would make it possible for the laboratory director to pursue the objectives set for the laboratory without being seriously inconvenienced by the time given up to consulting. Frequent requests for consulting services should be regarded as a particular mark of success of the laboratory. In addition to recovery of the scientist's salary, the laboratory should receive from Treasury Board and its departmental headquarters special consideration for staff budget increases over and above the average.

While temporary personnel exchanges among university, government and industry are desirable and should be encouraged, if industry R & D programs are to be successful there must be a greater mobility of full-time staff. Government must be prepared to see some of its best laboratories become active recruiting grounds for industry and even university. In fact, it must encourage it. However, present government regulations and procedures act against it. A particularly important problem exists with pension portability. It is clearly in in the national interest for government to take the initiative in making its pension plans for scientists and managers fully portable within Canada.

Industry has a clear interest in developing certain types of research and development engineering under its direct control. There remain other areas where it does not wish to venture. For example, while the oil industry is prepared to undertake work associated with oil extraction and recovery, it looks to government or private consultants for environmental and general oceanographic information. A particular need exists for detailed atmospheric and ocean weather and ice condition forecasting. Valuable services might be based on data already available or being collected through various government oceanographic and meteorological data centres. But these centres do not now have the staff to cope with such special detailed demands. It would seem quite appropriate for government to set up immediately special interpretation units in connection with these data centres. Their main function would be to develop a flow of information of use to the offshore industry. Once shown to be operational, these interpretation units could be split off as private Canadian consultant companies. We believe that this might well be undertaken by the Canadian Ocean Development Corporation.

This section would be incomplete if no mention were made of the need for careful scrutiny of the present Canadian tariff system. There still exist tariffs designed to produce government revenue, rather than to assist in the formation of Canadian industry on an equal footing with foreign competitors. Further, Canadian tariff policies can actually *penalize* Canadian industry. For example, a Canadian entrepreneur may be interested in manufacturing instruments competitive with foreign imports. Usually he must use some imported components. Most of his test equipment will also be imported. Both test equipment and components are subject to duty.

But, when he comes to sell his instrument, he finds his major market to be government and university laboratories. By special dispensation, neither government nor university is required to pay duty.

Thus the Canadian entrepreneur is faced with a *negative* duty when he tries to sell in his own home market. His customer must pay, indirectly, a partial duty on the Canadian product but need pay no duty at all on a foreign import!

Since the area of scientific instrumentation is one in which it would seem especially unwise to enforce any kind of "buy Canadian" law, we regretfully conclude that consideration should be given to removal of the duty-free status for these major consumers of scientific equipment. This may well work a hardship on laboratories in the marine area, which we believe generally spend too little on equipment purchase and development. Special account of this should be taken in financial allotments after tariff adjustments.

More sweeping tariff action should be considered. In the oceanographic instrument field, even the entire world market is rather small. To chop it up into segments partitioned by tariff barriers seems to make little sense. In our opinion, mutual abolition of tariff barriers on oceanographic instruments should be negotiated with any country which proves willing. In particular, such agreements with Western European countries and with Japan would seem to offer advantages. A small subsidy could then be paid to overcome the "negative tariff" which was noted above.

The Provision of Major Facilities

Marine science and technology are as dependent on major research and test facilities as are the other "big" science and engineering activities, such as nuclear physics and atomic energy, atmospheric research and aerospace engineering, or computer science and communications. In Canada, marine research and development activities received their initial impetus from arrangements which have made oceanographic and fisheries ships available to a variety of users. If, as we believe, there must be a significantly large increase in Canadian marine science and technology to obtain maximum returns to Canada from the increased industrial opportunity in the sea, it is essential that we preserve the best features of our present system of providing facilities and enlarge it in keeping with the demand.

Ships

In the operation of research ships, Canada has evolved some procedures that seem to be unique in the world. Elsewhere it seems to be normal practice that each oceanographic institution has its own research vessel or research fleet. For a large institution with a sizable fleet, this works well enough, but research ships are so expensive that in many smaller institutions the ship seems to determine the research program rather than the other way around. In Canada, regional ship pools have been organized. They provide very great advantages. Small organizations can have access to ship time without having to be concerned with such problems as crewing and refits. They are under no pressure to use a ship just because it is there. Further, a number of oceanographic experiments require more than one ship at a time. If the importance of the operation is great enough, the Canadian system can make such experiments a possibility even for smaller organizations.

Another aspect of Canadian use of research vessels, which seems generally superior to that in many other places, is the fact that most cruises of Canadian research vessels have been planned to achieve a clearly defined single purpose. Fortunately, it has been generally recognized in this country that the efficiency of a cruise depends upon a flow of high-quality scientific data, and not upon the proportion of occupied bunks in the scientists' quarters. Operating in this fashion means that the number of scientists aboard is rarely large.

This fashion of using ships leads one to conclude that the ships should be no bigger than is necessary to do the required job. This is not to say that we have been unwise to build ships as large as the C.S.S. *Hudson* or C.S.S. *Baffin*, nor that we will never again build such big ships. Big ships may be necessary for their sea-keeping ability. They may also be necessary for a decently habitable environment on long cruises in such inhospitable regions as the Arctic. In fact, *Hudson* is considered by those who work in her to be the best oceanographic research ship in the world, although she is by no means the biggest. However, these reasons of ability to do specific work should be the ones for building big ships, not the fact that big ships can hold a lot of scientists.

Contemporary research ship use, with shipboard computers available, calls for a good deal of data analysis during the operation. Intelligent use of ships requires a close watch on the progress of the operation so that it may be modified according to the results being received. We must not get in the position–only too common in some places–that ship usage and ship time are so tightly scheduled in advance that modifications may not be made during a cruise. This is what conspires against multipurpose cruises. Every cruise should have a *prime purpose and a chief scientist* who is recognized by all as being the final authority in the scientific program and in any change of this program for scientific reasons. Without such an explicit policy, it is not a simple matter to avoid conflicting interest among scientists aboard for a long cruise. If scientists other than those connected with the prime program join in a cruise, it must be on the understanding that their work is distinctly secondary and under no circumstances interferes with the prime purpose. It will be the duty of institution heads and of the committee operating the ship pool to ensure that each of the various interests has its turn as prime user of ship time.

The ship pool concept should be maintained and might well be expanded to include ships that were not originally intended as research ships. There seems to be no special reason why it could not be extended to all of the government-owned ships in a region. We wish to make it perfectly clear, however, that by this we do *not* mean that all of the ships should be operated by a single agency. In a foregoing section we have, in fact, noted that the government practice of centralizing service functions in special agencies, not familiar with or interested in the special functions of the user agencies, creates special difficulties in research. We suspect this is true for other areas such as icebreaking or sea rescue as well. It is often advantageous for individual research institutes to have particularly close relationships with certain ships, to understand their capacity for special work, to familiarize crews with scientific operations and scientists, and to plan modifications. Every ship should be designed and outfitted for the needs of a particular organization, for the attempt to make them too "general purpose" seems to be the reason why some of our ships are not particularly suited to any purpose. Modifications may be introduced to make the ship more flexible, but in the case of oceanographic vessels this must not be at the expense of reducing its effectiveness for the prime purpose of its design. We endorse the thesis advanced by the Canadian Committee on Oceanography that particular organizations have different and unique ship needs which require that they should be designated as *prime users* in design discussions and should have major responsibility for these ships in operational programming. Nevertheless, it should be possible to specify a range of functions for which ships are considered useful, and where these can include research and development, to regard them as part of a ship pool. Scheduling should then take account of priorities established by the Canadian Committee on Oceanography or its regional working groups.

There are certain areas where attention will have to be given to the best means of providing additional sea-going capacity. For example, a serious shortage of ship time for oceanography now exists on the west coast of Canada. This situation resulted from the withdrawal of one of the ships owned and operated in the ship pool by the Department of National Defence. It is aggravated by the fact that most of the ships owned and operated by the Fisheries Research Board, by the Fisheries Branch of Fisheries and Forestry, by the Department of Transport, and by the Department of National Defence, are either not effectively assigned to ship pools on the grounds that they are fully occupied by the priority programs of the agencies, or not designated as suitable for research operations. While fisheries research requires specialized vessels, fishing vessel design does not usually exclude them from physical oceanography. It is our contention that program priorities for the ocean-going vessels of the Fisheries Research Board should therefore be subject to review as part of the regional ship pools.

It is understandable that some of the larger special service ships of the service agencies or departments are not well adapted to research and development activities and have some absolute service program priorities. Fortunately, their "owners" have in the past usually displayed a spirit of co-operation in joint exercises. Thus, the Department of Fisheries and Forestry has made its ships available for programming in fisheries and related oceanographic development and some research activities whenever it is possible to spare them from other duties. The department has provided special equipment and made minor structural modifications where this is feasible. The Department of Transport has been responsive to the needs for support of government research operations, especially in the Arctic, and in the handling of small submersibles. The Department of National Defence has made its ships available in support of industry development projects with defence application. These exercises suggest that there are marine activities in the research area for which these service ships could be made suitable. At the moment, arrangements are generally on a bilateral basis, sometimes made possible through special discussions in the Canadian Committee on Oceanography. While it is most important that these joint endeavours should continue to be guided principally by the spirit of co-operation in the national interest, the present informality may not be sufficient to support the increased demands which we foresee. At least part of the fleets of these service agencies should be designated as suitable for research support, and limited or "conditional" programming should be done from within the regional ship pools.

If our proposals for a Canadian Ocean Development Corporation are adopted, there will be a need to consider new special ship needs associated with its activities. This will eventually lead to special construction. However, it would be wasteful of total resources not to use existing government ships as test vehicles for special equipment or as demonstration units for Canadian equipment to potential purchasers. Until the private demands are sufficient to justify full-time ship use, government should consider arrangements whereby it could make its ships available to support Canadian industrial development activities on a *high-priority basis.*

Throughout this report we have repeatedly emphasized the industrial expansion aspects of government research operations. The same considerations, of course, apply to the service areas. In this connection, there are particular problems that can be seen now in the Arctic. There are Canadian industries which are operating in the Arctic but whose operations could be enhanced by the availability of an icebreaker. These requirements are insufficient at present to justify a private venture into the icebreaker field. This situation will change rapidly, and there is even the possibility that, regardless of the position of Canada with respect to sovereignty over Arctic waterways, foreign-owned industry such as the oil industry will, if it decides to attempt surface ship oil transport in the Arctic, bring pressure to bear on Canada to accept the importation of foreign-built and foreign-owned icebreakers. There seem to be good reasons for Canada to plan and build an icebreaker fleet which is in excess of current demand. As was the case in Arctic air transport, pioneered by the Canadian Armed Forces, these government-controlled fleets can retire from those parts of the scene that Canadian industry becomes capable of handling by itself.

In keeping especially with the foregoing with respect to Arctic transport and survey, but also in connection with the needs of industrial expansion generally, the Canadian Government might well review its entire civil ship-operating and maintenance activities, in anticipation of possible new arrangements which can best enhance this industry. In an earlier section we noted that the Canadian fleet of oceanographic vessels is already large, although it is not by any means adequate for an expanded program. Viewing this in the light of a worldwide expansion in oceanographic activities, we have advanced the proposition that there is an opportunity for a world market for special research vessels built in Canada. Added to this research activity is the certainty of a growing industry need in the marine development field. While we have a respect for the ship design capacity of the Department of Supply and Services and for present government ship-operating procedures, there is always some reluctance by government to depart from conventional design. It also appears difficult for it to lease its ships to industry on a regular basis. Rarely is there an opportunity to retire them early. The purposes of improved design and industry expansion might be better served if government were to embark on a policy of encouraging private Canadian industry to build and operate research and special service or development support ships on the basis of guaranteed contract periods of the order of five years. In a preliminary study of such a system, by a government employee known to us, a private company offered to build a ship designed to meet government research requirements. On the basis of a long-term (three to five years) contract for a specified nine-month period in each year, the contract price was well below bids for short-term contracts, and compared favourably with costs of a comparable government-owned ship. This was made possible because the owner had alternative commercial use for the vessel, and because his refit costs were arranged as part of his normal operations. A private operator of this sort is in a better position to arrange for the export sales which would promote faster turnover, hence improved design. Not all of the government research or service requirements for ships could be readily adapted to such a scheme. But a significant proportion of the requirement for ships in the 500 to 1 500 tonnage class probably could be thus adapted without any sacrifice to the science and technology program. There is such a prospect for national advantages in a scheme of this sort that we urge early serious study.

Aircraft

There are a variety of uses for aircraft in making oceanographic observations, and the rapid development of high-speed towing techniques and "dunking" systems are certain to mean that applications to marine activities will increase. At the moment, oceanographic research institutes make limited use of them. As in the case of ships, aircraft needs are reviewed by the Canadian Committee on Oceanography or its working groups. Aircraft are expensive and require special maintenance and, where possible, agency needs have been served by present aircraft-operating agencies such as the Departments of Transport or National Defence, supplemented by private charters where suitable craft are available. At the present time, there would appear to be room for increased use of private operators, although, especially in the case of any substantial increase in western Arctic activities, special provision will have to be made for adequate funding of the laboratories and possibly the development of specially instrumented aircraft.

In one special area, air-sea interaction, the work is already of a degree of sophistication that calls for specially instrumented aircraft. In addition, the research purposes make it important to have specially trained and experienced crews. It happens that, for quite unrelated reasons, the National Aeronautical Establishment of the National Research Council has develop significant capacity in almost all of the requisite aspects. It has also acquired a very competent instrument section familiar with the problems of designing aircraft-borne instruments. We believe it would be desirable that all government aircraft intended for atmospheric and air-sea interaction research be concentrated in this Establishment, and made available to university, government and industry research from a users' pool analogous to the present ship users' pools.

Small Submersibles

Possible applications for small submersibles in Canadian oceanography have been actively investigated during the past two years. The number of uses in both research and industrial activity appear to be enormous. Canada has a peculiar advantage in this area, made possible by the ingenuity, patience and persistence of the founders of International Hydro-dynamics Inc. of Vancouver. They have built and now operate the only wholly privately owned and profitably operated small submersibles in the world. The design and performance of their craft are of very high calibre and they have shown a remarkable capacity for design modification to adapt them to a variety of uses.

Various government agencies have indicated to the Canadian Committee on Oceanography, through the Department of Industry, Trade and Commerce, their projections for expanded use, and in some cases interests in purchase, when budgets permit venturing into this new area. But while the potential applications in oil recovery, Arctic survey, pollution control, search and rescue, and fisheries research, to say nothing of defence interests, are indeed great, these activities have not yet generated much real demand. It is in the general Canadian interest to ensure that this important pioneering industry is encouraged to continue and to expand its activities in Canada.

Test Facilities

It is probably impossible for anyone who does not have first-hand experience to appreciate the sometimes incredible difficulties of operations on and under the sea surface. Quite apart from the weather, the requirements for making watertight seals for electrical equipment, resisting corrosion or withstanding enormous pressures, make land-based experience of little value. Instrumentation and construction units require the most rigorous of testing. To serve a number of its own needs, the Department of National Defence has set up a Test Establishment in Montreal, operated under contract by private industry. The apparent success of the Establishment suggests that it is a suitable model. However, its facilities already appear to be fully utilized, and in any case, its pressure-testing facilities are limited.

In a program for expansion of marine activity, there is a need for early provision of much-expanded test facilities. Special pressure-testing facilities to take units of a size that are likely to be utilized in oil well-head completions or in small submersibles would provide decided advantages in research, development and industry. From our review of marine activities and organizations in Canada, we have concluded that the federal government should encourage development of additional test facilities, either at the provincial research council laboratories, or with local industry along the lines of the Naval Engineering Test Establishment. As has been pointed out in Chapter IV, there is need for limited facilities on each of the coasts for the testing of ship designs. These could well be associated with the pressure-testing facilities advocated here.

The organizational responsibility of arranging for major test facilities should be accepted by the Canadian Ocean Development Corporation.

The Development of Centres for Marine Science and Technology

Co-operation among different research laboratories has a long and fruitful history in Canadian marine science. It first developed as a conscious policy on the west coast. In 1950 there was a small group of oceanographers forming the Pacific Oceanographic Group (POG) of the FRB Station at Departure Bay, near Nanaimo. In Esquimalt, near Victoria, was the new Pacific Naval Laboratory (PNL) of the Defence Research Board. At University of British Columbia in Vancouver was the fledgling Institute of Oceanography, which had just been set up to meet federal government needs for professionally trained oceanographers. It was quickly realized that these small groups would be a far more effective force working in concert than separately. There is a tradition of easy co-operation on the west coast, and an informal but nevertheless effective co-operation soon emerged–not only among the three groups mentioned above, but also with the Canadian Navy at Esquimalt, who manned and operated the first research ships used there, and with the new Department of Oceanography at the University of Washington. For example, even the earliest PNL cruises for the study of underwater sound transmission carried POG personnel who obtained data on the water structure. In the 1950s the best oceanography in Canada, and some of the best in the world, was being done at this west coast complex.

In the early 1960s, concerted federal government action threw the weight of support to the east coast. Already in existence were an FRB Technological Laboratory, laboratories of the Nova Scotia Research Foundation, and the NRC Atlantic Regional Laboratory. The Defence Research Board's Naval Research Establishment (now DREA) already had a solid record of accomplishment. Now a second new university Institute of Oceanography–that at Dalhousie–was started. Then the Bedford Institute of Oceanography was set up at Dartmouth. The combination gave promise of a co-operative research centre even more effective than the west coast one. Not only were there two federal government laboratories bigger than the corresponding west coast ones, but all the units were within easy reach of each other, so that much tighter collaboration could be established than was possible on the west coast, where anyone wishing to visit another laboratory had to give up a day to the visit. Now it is the Halifax-Dartmouth Research Centre that forms the model.

The advent in the Halifax-Dartmouth area of major new facilities for oceanographic observations and laboratory analysis, and of the university institute with its characteristically broad representation of disciplines directed toward an interest in the sea, provided a nucleus around which the originally apparently different responsibilities could develop common interests. In a short time it became possible for a scientist in one laboratory to discuss aspects of his problem with one in another, or to find in another laboratory a piece of equipment which he could use with profit. Research projects planned, executed and reported jointly among workers of different laboratories became a reality. In this favourable environment, the Fisheries Research Board established a new Marine Ecology Laboratory within the (renamed) Bedford Institute in association with the Atlantic Oceanographic Laboratory of the Department of Energy, Mines and Resources, and the Nova Scotia Technical College established an ocean-oriented teaching and research program. With the encouragement of the Canadian Committee on Oceanography, the Maritime Forces Command, the Meteorological and Marine Branches of the Department of Transport, and the Maritime Region of the Department of Fisheries increasingly made their facilities available as services to the research and development community, in exchange for a growing body of information of direct use to their own operations. Not only has it now become common for the laboratories and service units to operate in concert, but an ever-increasing degree of joint planning and exchange of information for budgeting purposes has taken place.

Such exchanges have gradually become consolidated at the operational level. For example, Dalhousie University has formally appointed individuals from the Nova Scotia Research Foundation, the Bedford Institute, and the NRC Atlantic Regional Laboratory to the staff of individual departments and the Institute of Oceanography in their role as scientists and graduate instructors. The Atlantic Oceanographic Laboratory of EMR and the Marine Ecology Laboratory of FRB have founded, and jointly program and fund, operational groups within the Bedford Institute. The Atlantic Regional Laboratory of NRC has established an Advisory Board on which it has named directors of the Institute of Oceanography at Dalhousie and the Marine Ecology Laboratory in the Bedford Institute. In addition, most of the operational and research agencies conduct joint reviews of plans and programs in the East Coast Working Group of the CCO. Thus there has developed in this Halifax-Dartmouth area a truly closely knit centre for oceanography, which is much more than a simple collection of individual marine-oriented laboratories and service units.

With the great variety of possible uses of the sea, related to the many different functions of various levels of government and of society, this operational level blending of the separately established and administered agencies is a gratifying development. It appears to have gone far to solve the complex problems that were discussed some ten years ago by the Glassco Commission in its recognition of a need for a broadly based national program in oceanography. At the time, it appeared that this might require the establishment of a Marine Council outside federal departmental jurisdiction, balanced by research which was required by individual departments and properly carried out within them. From the point of view of policy implementation, this Halifax Oceanographic Centre must be regarded as a highly successful, albeit incomplete, experiment in the administration and execution of oceanographic work.

Formally, the organizations which interact at the operating level in this Centre do not meet again in the administrative hierarchy of government until one reaches the level of Cabinet Committee, and even here the federal-provincial interaction is not entirely clear. In effect, the smooth operational functioning has developed from the contiguity of a large number of highly qualified staff who could develop mutual respect. Its continual development has been made possible through the existence and operation of the Canadian Committee on Oceanography. A most important aspect of this is that the co-operation begun by mutual respect has been able to develop and enlarge by a development of real interdependence. With the growth of activity, each of the units in the Centre has come to have something that the others can use–perhaps a service, a major piece of equipment, an expert or a ship. Here lies a key to all such developments. Research monopolies, while administratively easy to conceive and convenient to operate, are destructive of creativity, internal criticism and voluntary collaboration. They should be avoided.

We have specified that the Halifax-Dartmouth experiment is incomplete partly because the process of interaction of the research and service functions in the area is still undergoing active development. Furthermore, with the creation of excellent facilities and a strong scientific community, the influence of the Centre is only beginning to be felt in other parts of the country and internationally. Mutually advantageous exchanges and co-operative programs are being developed with a number of "outside" organizations, at McGill University and the National Research Council, Ottawa, for example. However, the experiment is incomplete largely because the effectiveness of exchanges with industry has not yet been well tested.

The oil companies have displayed keen interest in results of geological and geophysical programs. Certain smaller companies have been encouraged to manufacture and market instruments. Fishing companies have begun to take an interest in studies of distribution and problems of searching for fish. However, while much of the research can be classed as applied research, there has as yet been little activity in industrial development, outside of certain major undertakings by the Defence Research Board, such as the well-known hydrofoil project. It is our belief that this gap must be filled with formation of the Canadian Ocean Development Corporation. Some of its operations should be carried out in relation to this complex.

The success of the Halifax-Dartmouth experiment leads us to the conclusion that it should be used as a model for oceanographic developments needed elsewhere in Canada. For example, there is a clear need for much better oceanographic knowledge of the North Pacific in such areas as physical oceanography, geology, geophysics and biology.

The situation on the west coast now has several very unfortunate features. Not only are the three principal laboratories–the Pacific Oceanographic Group, the Institute of Oceanography, the University of British Columbia, and the Defence Research Establishment Pacific (formerly Pacific Naval Laboratory)–still as widely separated as ever, but some aspects of federal government policy and policy changes have been unfortunate. In the mid-1960s it became known that the Department of Energy, Mines and Resources intended to build a west coast laboratory somewhat on the model of Bedford. The intention was that the Pacific Oceanographic Group be moved into this laboratory as had the Atlantic Oceanographic Group been moved into Bedford. However, a succession of government austerity programs, plus the urgent imperative of setting up a freshwater institute on the Great Lakes, have delayed this project and it has still not been put in hand. POG has been carrying on a sort of holding operation. It has been FRB policy to keep it from expanding, since the expectation was that it would soon be mingled with a larger EMR laboratory, which would provide the necessary range of expertise. The whole state of uncertainty has been very hard on the morale of personnel at POG and within the EMR western unit. Activity of the Department of Energy, Mines and Resources is now gradually growing and several appointments have been made, although no central facilities have been constructed. It is urgently necessary that a site for the EMR laboratory be chosen and a timetable for construction set out–if only to give a sense of hope and purpose of these dedicated scientists.

The University of British Columbia also has its troubles–not with personnel but with accommodation. The Institute is still housed in a series of converted wartime barracks, and the number of graduate students and postdoctoral fellows that it can keep at any one time is limited by accommodation. Very competent personnel are working in tiny basement rooms with inadequate services. The Institute is to get, in the immediate future, a small amount of space in a new building on the U.B.C. campus. But it will be far from adequate, and may even have some adverse effects, in that it will force the physical separation of some of the people in the Institute. This will reduce the close collaboration between groups with various specialties, which has been such an important component of the strength of the Institute.

The origin of this problem is easy to find. Constitutionally, education in Canada is a provincial responsibility. However, it is not hard to see why the Government of the Province of British Columbia has felt no special responsibility to the Institute of Oceanography. Its students are drawn almost uniformly from across Canada. It was set up in the first place at federal government instigation. Its graduates have been employed mostly outside of British Columbia, and those employed in British Columbia have gone mostly into federal government laboratories. But this situation is rapidly changing. A number of new marine technology-based industries have been established in British Columbia over the past five years, and will employ an increasing number of highly qualified specialists. Thus the direct stake of the provincial government in marine science and technology has increased markedly. This surely calls for a more positive attitude on its part.

Similar problems have been overcome in the Atlantic Provinces because of the fact that these are areas slated for regional development, and so eligible for special federal government consideration. Both Dalhousie and Memorial University have been able to get federal government support for facilities in this way.

The arguments expressed above, which show that the provincial government has no special stake in this Institute, go on the other hand to show that the federal government does have a continuing stake. Surely it is not beyond the wit of the federal government agencies to find some way to provide a share of the capital support to the U.B.C. Institute of Oceanography.

The present situation on the west coast poses further problems in creation of a major centre on the Halifax-Dartmouth model. It is certainly true that there has been an easy tradition of co-operation. But this has been due to the spirit of individuals, which has been sufficient to overcome the inconvenience of physical separation. Whatever may be said for it, it is a tenuous circumstance on which to build; there are strong reasons to consider deliberate concentration of the scientific effort and its management in only one of these localities. In choosing the locality, there is no doubt that account must be taken of the fact that strong university participation is most important to the success of the Centre. The University of British Columbia is clearly best qualified, not only because its Institute of Oceanography is already one of the best centres for training in physical oceanography in the world, but also because of the orientation and excellence of its Department of Zoology, Institute of Fisheries, and Faculty of Engineering, all of which can play a most important role. This university strength alone is a compelling argument for the choice of the Vancouver area. But, in addition, the B.C. Research Council already has its laboratory there, and even more importantly, Vancouver is clearly the centre where major industry is developing.

A number of arguments have been advanced in favour of alternative sites. It has been argued, for example, that there is no available waterfront property in Vancouver from which to operate oceanographic ships. There are certain advantages in having ships, and especially the heavy machine dockyard facilities, near the scientific centre. However, except for the Halifax-Dartmouth Centre and the Woods Hole Oceanographic Institute in Massachusetts, no other major world oceanographic centre has this advantage. The separation of scientists and ships does not appear to have adversely affected operations of the Institutes of Oceanology and Fisheries in Moscow, the National Institute of Oceanography at Wormley, England, or the Scripps Institute of Oceanography at La Jolla, California. In our view, the logistic problems associated with separation from the ship base are overshadowed by the inefficiencies of fractionization of the professional scientific and technological community. There are many examples to show that isolation of a small group of scientists or engineers from an active community of their peers leads to intellectual sterility. In our view, no arguments about the potential inconvenience of a Vancouver site close to the University of British Columbia outweigh its assurance of a vigorous scientific and technological community.

We are forced to admit, though, that no ideal solution is in sight. The university Institute must continue to be in

Vancouver for the reasons stated. On the other hand, the Maritime Command base is in Esquimalt, and these are very strong reasons for keeping DREP there, in close contact with its "customer". The new EMR laboratory must go in one place or the other, and POG must join it. We recommend Vancouver. One group at least will be cut off. We believe that very serious consideration should be given to the full-time assignment of a large helicopter to this west coast centre. It could be used for research. (In fact, helicopters have already been used to good effect by research groups in the area.) It could also be used as a mode of transportation which cuts to one third the time required to move between Vancouver and Victoria. There are precedents. Scientists at Massachusetts Institute of Technology in Boston have made considerable use of helicopters to keep in close contact with Woods Hole, even though the two centres are connected by a good high-speed highway.

The problems of organization of studies and development of the oceanographic, terrestrial and atmospheric aspects of the Arctic are greater than any presented by local geographic problems on the west coast. The Arctic is clearly an area that requires high-priority consideration in Canada and must soon be developed. At the present time there is considerable research familiarity with sea-ice problems and experience with high Arctic conditions at the Defence Research Establishment Pacific in Victoria, Defence Research Establishment Ottawa, at the Arctic Research Unit of EMR at Victoria, at McGill University, and at the Bedford Institute. In addition, the Polar Continental Shelf Project of EMR operates from Ottawa. There is substantial Arctic logistic experience in the Armed Forces base at Comox, B.C., near Edmonton, and in the Maritime Provinces, and DOT bases in the Maritimes have considerable experience in Arctic ice and meteorological survey. Oil companies have been rapidly developing their experience in airborne logistic support of Arctic operations out of Edmonton. Government and industry have operated icebreakers and Arctic sea transport from east coast bases.

In considering an approach to Arctic research, it seems appropriate to consider the Canadian high Arctic as two regimes rather than as a single area. The western high Arctic, including the Beaufort Sea area, is icebound for most of the year, requiring much greater emphasis on surface ice and air operations. A glance at the map, however, shows that the eastern Arctic, including Hudson Bay, is much more open and lends itself much more to seaborne operations. The two regions are different in other ways as well. It is the western Arctic, with its very thick sediments, that offers best prospects for oil and gas. An important component of future activity in the eastern Arctic will almost certainly involve movement of metal ores from island bases by ship.

In view of such factors, it would seem reasonable for Canada, at least initially, to develop oceanographic and possibly other aspects of its Arctic research and development programs from two centres. Western Arctic studies could well develop in connection with the proposed west coast oceanographic institute. They would, however, be likely to operate logistically through Edmonton and might well develop a special relationship with the University of Alberta there. Similarly, eastern Arctic studies could, as suggested by the Glassco Commission, be developed from the Bedford Institute. In the latter case, however, special consideration will have to be given to taking full advantage of the Arctic expertise and experience which is present at the Marine Science Centre of McGill University and the Arctic Institute of North America in Montreal. Important work on ice and in Arctic conditions generally is also developing at Laval University and may form an important base for participation by French Canadians. It must also be ensured that this eastern Arctic program is integrated with the major Gulf of St. Lawrence project, which we propose partly as an experimental model for it.

Finally, we wish to make clear the view we have developed during our study of the relationship between the Canadian oceanographic centres and the various other university centres which are proposed or have been set up for marine research, principally in marine biology. As we have indicated earlier, we believe that any of the marine research that requires facilities larger than small launches should be carried out in the major oceanographic centres at Halifax-Dartmouth and Vancouver. The support of individual university ventures in the marine field, or of the two consortia which are proposing to set up facilities at St. Andrews, New Brunswick, and at Bamfield, British Columbia, are to be judged on their merits as educational institutions necessary to a proper training in both the classical biological and the environmental scientific disciplines. We are convinced that there is a particular and genuine need for the student field-training facilities at St. Andrews and Bamfield. We have also noted that there may well be certain extra advantages to be derived from the presence of these private university centres. That is, the staff and students will be engaging in research projects. Some of these may well be of significance in the general struggle to maintain a high-quality environment. The funds to support research in these fields should, however, be obtained in the usual way as research grants from the National Research Council, primarily on the basis of their scientific merits, or as grants, contract funds or support in kind from government departments for research relevant to departmental objectives.

Relations with the Provincial Research Councils

Seven of the ten provincial governments of Canada have established non-profit research councils or foundations with the aim of fostering research in areas of economic importance to these provinces. Two of these, the Nova Scotia Research Foundation and the British Columbia Research Council, have, as might be expected, developed specific marine-oriented projects. In Nova Scotia, these include studies in productivity of seaweeds, in marine geophysics, and operations research in fisheries. In British Columbia, studies of problems associated with marine borers in logs and marine pilings, in wave studies, and in the general field of data processing have been developed.

These research projects have usually been initiated to fill a gap in understanding of a problem which was of local importance. However, the level of scientific expertise has generally been high and the knowledge generated is applicable to other areas of Canada. The British Columbia program in marine borers is a good example. Recently the B.C. Research Council has received contracts to monitor marine borer infestation rates on the Canadian eastern seaboard.

In addition to the fact that they have demonstrated an ability to do good research with wide application, the provincial councils exhibit other features which recommend them. In particular, they have not only developed in response to local industry problems, but have maintained contacts with this industry. Almost all of them employ technical information service officers whose job it is to familiarize themselves with this industry. They are thus able to disseminate information to it through repeated personal contact. They also attempt to foresee problems which industry either has not anticipated or does not have the ability to solve, since they depend for part of their financing on money earned in contracts with private business or other government agencies to carry out specific projects. They have a knowledge of local conditions and local potential which is possessed by very few other agencies, with the possible exception of the knowledge of farm problems developed by field representatives of the Department of Agriculture.

Throughout this report we have emphasized the need to promote the transfer of scientific and technological knowledge from laboratories to industry. It is apparent that the provincial councils have already addressed themselves seriously to this task. In the growth of activity in the marine field, it is important for the country as a whole to take full advantage of their experience. There would appear, for example, to be special advantages in channeling work in development of certain kinds of marine sensing and measuring instruments through the provincial research councils, which have the engineering ability and are probably the most knowledgeable about the financial and technical capacity of local industry to manufacture and market them. In the rapidly growing marine science area, they may also be in a better position than is most small industry to sense the problems and trends in both science and technology which will call for modifications or further development of existing instrumentation. They may also be expected to play an increasing role in the development of fish culture methods, particularly when these reach the stage of pilot farms.

The provincial research agencies have a special role to play in dealing with research and development projects which are of about the same scale of size and time as is dealt with by most of the local industry. They thus supplement, rather than compete with, the larger nationally oriented federal government laboratories or industry research laboratories in the business of making commercial use of our science and technology. Their potential and experience should be fully understood and developed by the Canadian Ocean Development Corporation.

There is, however, one potentially serious problem which the provincial councils must bear in mind, and which was brought to our attention during this study. One of the criteria of success of the provincial research councils is the number of contracts they obtain. An increasing number presumably reflects customer satisfaction. However, in some of the areas where they can provide a service to industry, they may eventually find themselves in competition with private industry. Since the government agencies are by definition non-profit, they are often likely to be preferred to private consultants by anyone paying for a service.

As industrial activity in any area develops, the possibility of a market in associated services also increases. In many cases, appropriate action by either provincial or federal research and development agencies may promote the formation of private consultant or other service industries. It is part of the task of the director of a research laboratory to continually review his operations with this possibility in mind. To support him in this aspect of his work may require the development of the special administrative mechanisms discussed earlier.

Marine Science and French Canada

The implications of bilingualism in the scientific agencies of the federal government do not seem to have been fully studied. In the absence of any agreed policy, it is thus necessary to deal with marine sciences in isolation.

At this particular point in time, and probably for some time to come, the international language of science is English. Almost all international conferences, no matter in which country they are held, are in English (except for elaborate, formal ones which have translation services). Most important scientific literature is accessible in English, and much of it only in English. In Canada, the historical development of marine science was centred in English Canada, and because of the need for a good deal of centralization and co-ordination of effort, and because there can be only a *few* marine science institutes, the dominant language of marine science will continue to be English. Where does this leave the francophone Canadian. He can join the existing anglophone institutes and should certainly not be discouraged from doing so.

Indeed, he should be provided with French-speaking or fluently bilingual secretaries so that, if he wishes, he may do his scientific writing in French. Efforts toward bilingualism may become sufficiently successful that he may be able to use French in many of his own contacts within the institute. Nevertheless, he will be in an essentially English-speaking milieu. The language of the coffee break will be English. So will be the language of most of the people he and his family deal with in their daily contacts.

However, just because a French-speaking scientist must, for professional reasons, command English is not to say that he must live in English. It must be possible for a French-Canadian scientist to live and work in French if he so chooses. Surely most would so choose if given the opportunity.

The fact that marine science and technology cuts across classical disciplinary lines, and that an immense amount of work is necessary in the Canadian marine environment, provides a wide enough base for co-operation in this field. This gives French Canada an opportunity to participate in an activity which will have an increasing scientific and economic impact in the future. At the present time, French Canada is trying to develop a strong scientific and technological base; entry into the marine field would provide an outlet for French-Canadian scientists and engineers and help in the development of a strong scientific base, which could only benefit the rest of Canada. Further, the concentrated study of the Gulf of St. Lawrence which we propose is of obvious interest and concern to French-Canadians in the Maritime Provinces as well as in Quebec. Laboratories in the Province of Quebec, as well as in the *Centre de recherches sur l'eau* at Laval and other francophone universities, must make their bids to participate in this project.

At the moment we are in a self-perpetuating dilemma. There is, at the present moment, no sense in attempting to construct and staff a major oceanographic laboratory in French Canada. The cadre of highly qualified individuals needed simply does not exist (without disastrously raiding the universities). On the other hand, since there is no such laboratory, there is little motivation for French-speaking Canadians to consider marine sciences as a reasonable professional goal.

Although we recognize this problem, we also recognize that we are insufficiently versed in its many ramifications to suggest a solution, and must be content with pointing it out.

Managing the Major Projects

In this report we have called for the establishment of four major projects in marine science and technology in Canada. Two of them are described in Chapter II:

1. Learning to drill for gas and oil from the sea floor;
2. Under-ice geophysical survey.

Two others are described in Chapter V:

3. Control of the Gulf of St. Lawrence winter ice cover;
4. Study of alternative uses and environmental quality control in the Strait of Georgia.

It is our view that these projects would provide a suitable focus for a program needed to implement a desirable national policy for marine science and technology in Canada during the 1970s. The first first two are directed primarily towards the development of an independent marketable technology in secondary Canadian industry. The offshore oil industry appears a particularly suitable choice, since it is part of one of the most rapid growth industries in the world, and one which is likely to remain so for at least 20 years to come.[1] At the same time, it is an industry in which there is much room for technological advance.

[1]See, for example, Resources and man, a study and recommendations by the Committee on Resources and Man. National Academy of Sciences and National Research Council. San Francisco, Freeman & Co., 1969.

The third project is designed as a test of our capacity for far-reaching environmental change. The geographic area chosen is one where substantial change has already taken place and which, superficially at least, appears on the margin of becoming a different climatological regime. We need to know about it, anyway. But the reason for the choice of subject is much broader. Canada has a vast stake in environmental quality control simply because we have so much "environment", in which alterations probably mostly originate outside our own borders. There is a great need for development of international as well as national law and agreements on responsible use of this great "common property". With such an experiment in hand, Canada would have a much stronger voice in negotiations.

The fourth project shares some of the features of the third, except that it more clearly relates to a test of how much we know and how much we can and are prepared to do for ourselves. It is a domestic problem, but exhibits many features in common with local resource use in other parts of the world.

By specifying these major projects, we do not mean that there are no other major responsibilities for which we require marine science and technology. There are many reasons for doing this work, and general activity will have to be increased to meet them. There would be a marine program without these projects. However, by making them part of the total program, it is possible to see more clearly the relative contributions that could be made by the university, government and industry sectors, and especially how to increase the non-government participation. This should emerge more clearly from the next chapter. At this point, it is worth saying that we envision the projects as requiring approximately one third of our total marine research and development expenditures by the middle of the decade.

The management of these major projects may not be simple in detail. However, it is possible to suggest appropriate means for their initial development. This is especially true for the first two projects, which are clearly dominated by engineering and technological aspects. Information on ice drift and ice characteristics will be needed, and this will call for close liaison with the research side. But they are projects of a nature that should be under the direction of the Canadian Ocean Development Corporation. Co-ordination with research programs should come through the Canadian Committee on Oceanography and involve joint planning with the Departments of Transport and Energy, Mines and Resources and the universities.

The third and fourth projects are much more complex because they necessarily relate to many aspects of government policy, as well as require considerable operational capacity. Many facets of present research programs relate to them and will have to be co-ordinated. In considering a method of management, we were aware of *two sides to these problems*– a need for public participation in evaluating alternative courses of action, and a need for careful co-ordination of the research operation to ensure a sound and balanced program as a basis for decision. These two aspects are so different yet interdependent that they should be developed apart but simultaneously, with informational cross-linking. The first aspect is clearly the responsibility of a socially oriented but scientifically "non-operating" organization. It is our belief that discussions of such large projects should be systematically encouraged in and among the university, federal and provincial government spheres. In many ways it would appear reasonable for the Department of the Secretary of State for Canada, or even the Department of Regional Economic Expansion, to take responsibility for this aspect. If there were a Ministry of Science Policy, it might be the most appropriate.

The operational aspects of these projects will need to command the interest and support of the major operating departments. In the purely marine problems, the Department of Energy, Mines and Resources, or perhaps a future Department of Renewable Resources, will have to be involved. Because the Gulf of St. Lawrence project is at the centre a physical problem, the Department of Energy, Mines and Resources would be a most appropriate body for it. The west coast project is more heavily involved with living resources and recreational demands. The present Department of Fisheries and Forestry already has broad experience with these aspects of its work and would be an appropriate agency. These choices of departments seem particularly suitable to us because of the history of co-operation between them, and because they have or are developing regional laboratories and facilities on which operations might eventually be based.

Our own view of the management of these projects is that the named departments should be responsible for setting up steering committees for the projects. These would invite briefs from interested agencies, with special emphasis on universities in the scientific and sociological aspects, and on industry in engineering consultant and feasibility aspects. Their own departmental laboratories should be responsible primarily for reviewing the existing state of our knowledge and identifying the gaps. All groups might be represented in seminars and invited as well to present proposals and estimates of required funding. The aim for the first two years should be to assess our state of knowledge and our capability for carrying out such major research projects. The projects themselves should, however, be understood to follow the two-year study period for a period of, say, five to seven years, unless the feasibility study were to clearly show that the initial conceptions set out here are wrong and that all hope of manipulation or control is beyond a reasonable order of expenditure.

Even this conclusion would be of immense value to future policy formation!

Chapter VII

Projections

Introduction

Faced with the task of attempting to cast projections for the level of effort in marine science and technology for the next decade or so, we encounter a problem which we have skirted in the preceding chapters. That is, what boundary should one draw around *marine* science and technology? Our problem reflects, of course, one in the real world. If a ship is en route from Montreal to Europe, just where is it that it leaves the river and enters the ocean? Is a man who studies climatic fluctuations, of which so much is made in this report, doing marine science or is he not? Is it marine technology to design a buoy system for measuring waves in the Gulf of St. Lawrence and on the Great Lakes? If so, what about one intended for the lakes only?

As we have gone to some lengths to point out, marine science is a branch of the larger environmental science. The marine environment receives inputs from all other parts of the environment, so marine science interacts with all other areas of environmental science.

Clearly, any borders which we draw will be artificial ones. We will have to be largely arbitrary. In dealing with government departments, we are able to use artificial boundaries which government itself has drawn. Our principal attention will be concentrated on the Departments of Energy, Mines and Resources and Fisheries and Forestry, which carry the main burden of federal government research activity. In the technological field we attempt to consider the impact of the Canadian Ocean Development Corporation which we recommend. We are unable to say anything significant at all about what could be perhaps the largest single component of marine technology; that associated with ship building. The findings of the Water Transport Committee of the Canadian Transport Commission, and the federal government's reaction to these findings, could therefore have far greater impact upon that industry than will anything we deal with here.

With respect to the universities, our situation is even more difficult. For example, physical oceanographers and physical limnologists need and get almost identical training. Nevertheless, we must make the effort to define the needs for them separately. It is very important to the universities to have a clear idea of what the professional demand for different kinds of graduates at various levels is likely to be.

As scientists, we perhaps should throw up our hands–say that we simply do not yet know enough, and recommend further study. We recognize, however, that we must take the advice we have offered others from place to place in this report. Incomplete though our information be, we must use what we have to offer an opinion.

The Growth Curve

The growth of both organisms and organizations seems to follow a very characteristic curve. Roughly, it may be described by an initial exponential growth followed by a tendency towards saturation. Eventually the organism or organization loses importance and declines or suddenly disappears (dies). Very often there is a long time period in which saturation is closely approached. This period is referred to as "maturity". The height of a human being is a good example of such a curve. If the curve is plotted on a linear scale it forms an "S" shape–the so-called sigmoid curve. If it is plotted on a semi-logarithmic scale, the lower left portion becomes a straight line.

In Figures VII.1 and VII.2 we present, on a semi-logarithmic growth curve, our concept of the present position of the main divisions respectively of marine science and of development in the marine area. None of the fields which we consider is in a declining phase. (There are some: wooden-hulled ships and one-man commercial fishing for example.) We have taken the asymptote not to be a constant, but to be at the growth rate of the adult population, which is about $2\frac{1}{2}$ per cent per year.[1]

Approximately, the time base is a ten-year one. In this time the adult population is expected to grow by between 25 and 30 per cent, depending on the immigration-emigration figures. The "mature" areas near the top of curve cannot grow *much* faster than this–perhaps near the 4 per cent year suggested by Jackson *et al.*[2] Thus they may expect something like a 50 per cent growth in the decade. On the other hand, if a discipline is placed near to the 0.1 mark, we expect it to grow by a factor of more like ten in the decade–a growth of over 25 per cent per year. We recognize that the time scale should differ from one activity to another, and so the abscissae should have different scales. We also recognize that the "take-off" time for activities differs. Thus, apart from the fact that it is subjective, this representation is very crude. Nevertheless, the figures offer a useful summary of our opinion as to the status of various branches of marine science and of development in the marine field in Canada. The detailed order of things grouped closely together should not be taken too seriously.

[1]This rate should hold for the next decade if immigration-emigration figures remain at about the present value. The total population will grow more slowly, because of the dramatic drop in birth rate which has taken place during the last decade.

[2]Jackson, R.W., D. W. Henderson and B. Leung. Background studies in science policy: projections of R & D manpower and expenditures. Special Study No. 6, Science Council of Canada. Ottawa, Queen's Printer, 1969.

Projections for the Government Service

In Table VII.1 we display the distribution of professional staff now employed in marine science and technology in a number of government departments. "Other" consists of the National Research Council, Department of Transport and the National Museum.

Under "physics" we have grouped all those who might have been expected to have taken a first degree in that discipline. It includes physical oceanographers, acoustic experts, air-sea interaction experts, and those working in hydrodynamics related to the ocean. We have been forced to add engineers to this group because we can find no satisfactory way of separating them. Many persons trained in physics are employed full time at tasks which should be defined as engineering, and many graduate engineers are performing as physicists. We have also included in this group a handful of geophysicists who we know are doing engineering.

The category "biological oceanography and fisheries" might better be called marine ecology. These are the more

Table VII.1–Estimates of Professional Manpower Pursuing Marine Science and Technology Activity in the Federal Government Service, 1968-69

Discipline	Department				
	EMR	FRB	DRB	Other	Total
Physics and Engineering	82	12	77	11	182
Biological Oceanography and Fisheries		112		6	118
"Classical" Marine Biology		2		1	3
Chemical Oceanography and Geochemistry	10				10
Geology and Geophysics	35				35
Hydrography	15 +115				15 +115
Total	**142** +115	**126**	**77**	**18**	**363** +115

Notes: "Other" includes the Department of Transport, National Research Council, and the National Museum.
Not included are 127 engineers of the Department of Public Works, mostly engaged in coastal engineering projects, and 237 professionals associated with ship design.
Hydrographers are divided into a cadre and a larger group of individuals who are highly skilled but have usually not had a great deal of formal training.

Figure VII.1-Symbolic Representation of the Position on a Growth Curve of the Main Divisions of Marine Science

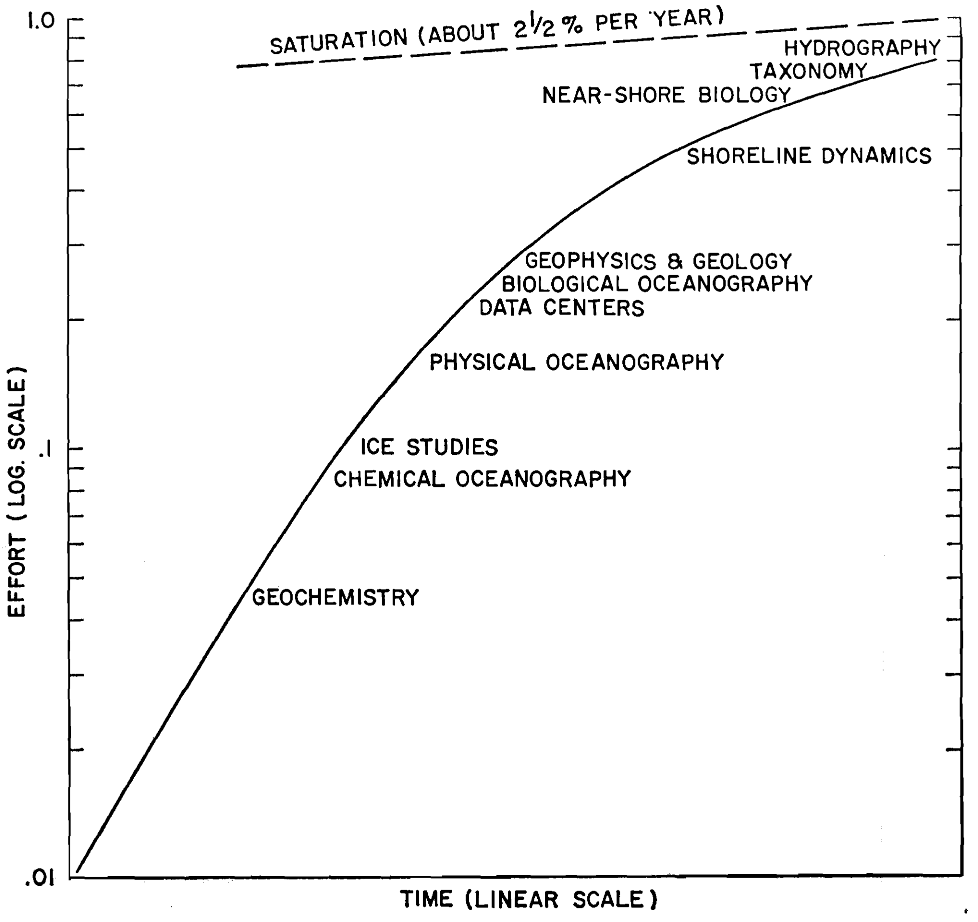
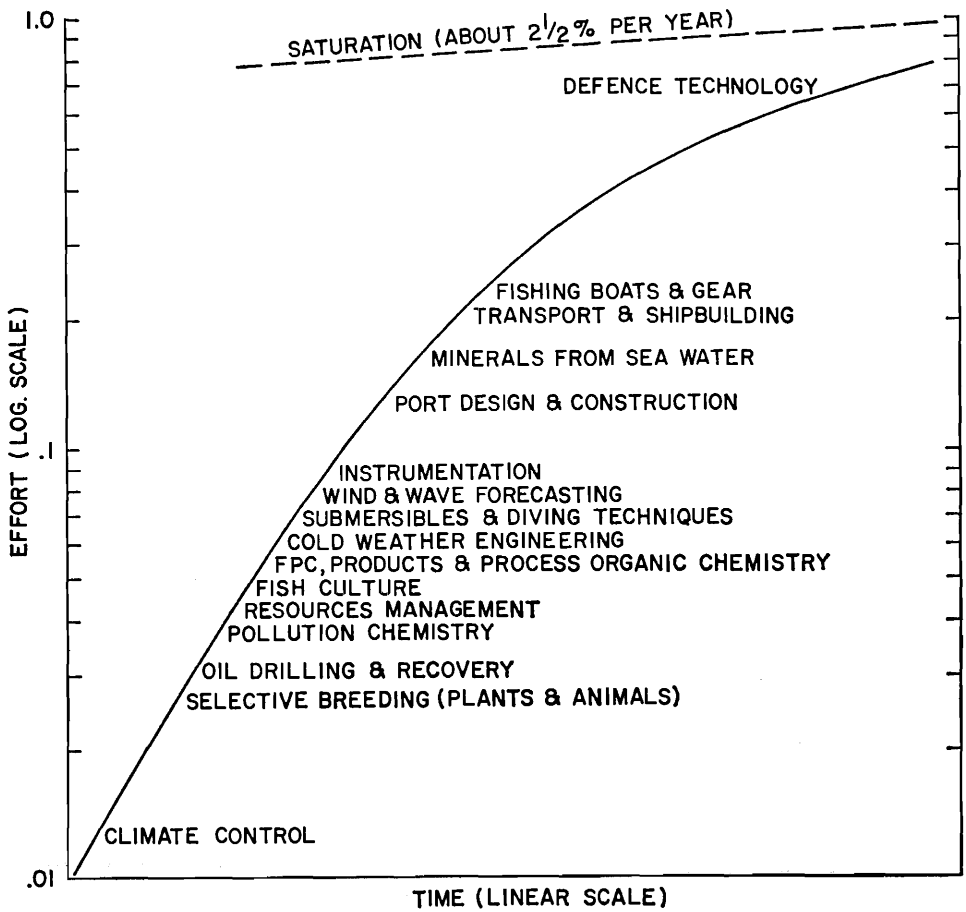


Figure VII.2-Symbolic Representation of the Position on a Growth Curve of the Main Areas in Development in the Marine Area



highly technically trained and quantitatively oriented individuals in biology who may or may not have first degrees in biology, but tend in any case to have strong backgrounds in chemistry, mathematics, and to a lesser extent, physics. It is they who will work on the population management and pollution problems. "Classical marine biologists", as we use the term here, are the more traditionally trained biologists oriented towards life history, taxonomic and "natural history" studies.

The division between geology and geophysics is not sharp, and we see no reason to separate them. We have taken the same view of chemistry and geochemistry.

In hydrography we find that there is a cadre of people who might have been included in the "physics" group, plus a much larger group of individuals who are highly skilled but who have not had much formal advanced training.

Table VII.2 displays our projections for 1980, based approximately on the growth curve of Figure VII.1 and on the needs which we have identified within this report.

Apart from the Canadian Ocean Development Corporation, the overall increase in effort in terms of manpower which we suggest is thus a factor of $2\frac{1}{4}$, or $7\frac{1}{2}$ per cent per year over the eleven-year period. The *growth* should be about equally divided between east and west coasts, so that the east coast based effort will remain greater than that in the west, but the disparity will be reduced. As for the distribution among the areas to which this effort is to be applied, we suggest a ratio of 2:1:1 for Atlantic (including the Gulf of St. Lawrence):Pacific (including the Strait of Georgia):Arctic (including Hudson Bay).

Financial Implications

In Table VII.3 we present the financial implications of our effort projections. Once more we have concentrated upon Energy, Mines and Resources, Fisheries and Forestry, the Defence Research Board and the Ocean Development Corporation. To obtain the figures presented, we have rounded the effort projection to the nearest 0.5 in factor of increase. For the research agencies, we have added 20 per cent to take account of the increase in equipment budget which was called for in Chapter III, p. 71.

Again we would point out that these sums would by no means all be spent inhouse. A large fraction would be employed in contracting out. In Chapter VI, we call for a $45 million per year input to the Canadian Marine Development Corporation for the first five years of its life, followed by a re-examination. For the 1980 figures, we rather arbitrarily estimate $50 million. The actual figures might be much larger or rather smaller, depending on the success of the organization as an investment which yields a return to Canadian society.

All these figures are calculated without allowing for any "sophistication" factor or for inflation. Jackson *et al.*[1] suggest a figure of 6 per cent for this factor. With that included, the sum to be spent in these areas of marine science and technology will rise from $51.2 million in 1969 to $300 million in 1980–or a factor of 5.85, which corresponds to a growth rate of 16 per cent per year. If overall Canadian expenditure on research and development rises at a rate of 4 per cent in effort and 10 per cent in cost, as is suggested by Jackson *et al.*[2], the eleven-year period will see an overall cost increase by a factor of 2.8. The growth which we envisage for marine science and technology will then lead to an approximate doubling of the proportion of total Canadian R & D effort applied to the marine field. We believe that it will then have reached a fair representation of its true importance to the nation.

Apart from the Canadian Ocean Development Corporation, the increase in funding indicated is from $51.2 million to $112.4 million (without the sophistication-inflation factor). This $2\frac{1}{5}$ growth factor is

[1] Jackson *et al., op. cit.*
[2] *Ibid.*

Table VII.2–Projections for 1980 of Manpower Categories Listed in Table VII.1

Discipline	Department						Increase 1969-1980
	CODEVCO	EMR	FRB	DRB	Other	Total	
Physics & Engineering	50	330	45	77	30	532	×3.0=11% per annum
Biological Oceanography and Fisheries			200		10	210	×1.8=5½%
"Classical" Marine Biology					10	10	
Chemical Oceanography and Geochemistry		35	15			50	×5=15%
Geology and Geophysics		90				90	×2.6=9%
Hydrography		35 +160				35 +160	×1.5=4%
Total	**50**	**490** +160	**260**	**77**	**50**	**927** +160	
Increase 1969-1980		×2.6 =9%	×2.1 =7%	×1.0 =0%		×2.3 =9%	

CODEVCO: Canadian Ocean Development Corporation.
Note: For some projects CODEVCO will undoubtedly employ professionals other than physicists and engineers, but the number will be insufficient to change the projection significantly.

Table VII.3–Projected Growth of Federal Government Expenditure in Marine Science and Technology

Department	1969	Growth Factor[1,2]	1980
	$000 000	$000 000	$000 000
Energy, Mines and Resources (EMR):			
Polar Continental Shelf Branch	2.1	2	4.2
Marine Sciences Branch without Hydrography	10.6	4	42.4
Marine Sciences Branch with Hydrography	10.4	1.5	15.6
Fisheries and Forestry (Resource and Industrial Development)	4.6	2	9.2
Fisheries Research Board (FRB) (Product Quality Research)	2.5	2	5.0
Fisheries Research Board (FRB) (Resource and Environmental Research)	10.0	2.5	25.0
Defence Research Board (DRB)	11.0	1	11.0
	51.2		**112.4**
+Canadian Ocean Development Corporation			50
			162.4
Total with sophistication-inflation factor of 6%			**$300 million**

Note: Detailed projections for DRB expenditures are at present uncertain. The figures quoted above should certainly prove to be conservative given, for example, the renewed interest by the Armed Forces in the Arctic.
[1]This "growth factor" does not take account of increases attributable to the sophistication-inflation factor.
[2]Over an 11-year period, a growth factor of 1.5 = 3.8% per year; 1.9 = 6% per year; 2 = 6.5% per year; 2.5 = 8.7% per year; 4 = 13% per year.

essentially the same as that for professional manpower, despite the 20 per cent we have added for increases in the equipment budget. This apparent discrepancy arises from the fact that hydrography, which is assigned a relatively small growth, is comparatively expensive per professional because of heavy use of ship time.

We have not separately budgeted the four Major Projects suggested in this report, except insofar as two of them are discussed in setting out a budget for the Canadian Ocean Development Corporation in Chapter VI.

The reason for this is that we believe that there will be a great deal of work carried out in the Gulf of St. Lawrence and the Strait of Georgia in any case. If the Major Projects are adopted as national policy, it is expected that this would lead to a concentration of efforts in these two regions. However, while the "Major Project" status is not likely to be achieved without the kinds of increase called for, the principal function of these major projects is to provide focus and point to the effort of the research community. If and when engineering works are shown to be needed, of course they will have to be paid for separately. However, we are unable to anticipate at this time even the nature of such works, let alone their costs.

Implications for Industry

We have expressed the view that the industry associated with our maritime opportunities is in only the early stages of a rapid growth phase. Nevertheless, it is already varied and possessed of considerable capability. We have received briefs or long letters from more than 75 companies, and have interviewed representatives from a number of them. The objects and services which those companies can supply cover such a wide range as to defy generalization. Manufactured items include special winches, buoys, cables, navigation and communication devices, pressure chambers, diving equipment, towed bodies, acoustic devices and small submersibles.

It is obviously impossible for us even to attempt any projections concerning needs for individual kinds of items or services. Overall, we can point out the following.

We expect that ten years from now offshore oil will be in the billion dollar per year class, probably multibillion. A large fraction of the sum will be spent on goods and services. If Canadian governments act with wisdom and if Canadian industry rises to the challenge, most of these goods and services will come from Canadian industry.

From government sources, about 95 per cent of the funds available to the Canadian Ocean Development Corporation will be employed in contracts to industry. As is shown in Table VI.1, only 5 per cent is to be spent in its own operation.

Of the sum suggested for the other agencies, perhaps one quarter should be spent on contracts with industry. Altogether, then, we expect that about half of the $300 million per year which we project for 1980 will be spent on contracts to industry. There will also be contracting from the universities to industry, but the sums involved will not be large enough to make any great overall impact, although of course they may be of considerable importance to some small firms.

Implications for Universities

Before attempting to offer projections which may be of help to universities planning for their part in the future of marine science and technology, it is advisable to attempt to put them into the context of the situation in which Canadian universities now find themselves. Twenty years ago only a handful of Canadian universities attempted to conduct graduate studies, and even fewer offered Ph.D. programs. Most Canadians wishing to pursue advanced studies had to go abroad –usually to either the United States or the United Kingdom. Since that time, there has been growth in each of four superimposed factors: population, proportion attending university, proportion of graduates proceeding to advanced degrees, and proportion of Canadian remaining in Canada for their graduate work. The result has been an increase in the number of graduate students in science and engineering, from 1 574 in 1954 to 11 500 in 1968. This growth rate of 15 per cent per year is to be compared with a population growth rate of about 2½ per cent. It is a symptom of the "population explosion" of university professors referred to in Chapter V. Clearly it *cannot continue for long*. (For those who like this sort of thing, it is a simple calculation to show that, at present growth rates, the population of graduate students in science and engineering would exceed that of the total population within 65 years.) In fact, signs of saturation are already appearing[1,2], and for the first time since the depression years it is no longer easy for all graduates with advanced degrees to find suitable employment. Within the universities, however, there remains a large fraction of the "the more the better" attitude toward graduate studies which was a completely reasonable stance only a few years ago. Situations change more rapidly than do attitudes. But the attitudes must now change.

Within the marine field, the impact of this changing situation is most strongly felt in marine biology. It is incumbent upon university marine biologists to take a hard look at their graduate programs in relation to the number of likely outlets for their students. In the course of our study, we found that disconcertingly little attention was being paid to this factor by many university faculty members. Figure VII.3 illustrates the point. Shown are the number of graduate students in various fields of marine science in the six universities of U.B.C., and Dalhousie (Institutes of Oceanography), McGill, Victoria, Simon Fraser, and Guelph. The disparity between biology and the other fields is actually much greater even than is indicated by these curves. The universities listed include almost all of the graduate students in Canada who are pursuing studies in aspects of marine science other than biology. For biology, however, there are students in many other universities across the country. In addition, both the Institute of Fisheries and the Department of Zoology at the University of British Columbia have students who could have been but were not included. So too has the Department of Biology at Dalhousie.

It is not our intention to say that the growth of graduate schools, even in marine biology, must now stop. As we have seen earlier in this chapter, there is little demand for these graduates in the government service, except insofar as their training can be given a strong quantitative interdisciplinary bent so that they may be useful in pollution studies. However, as is pointed out in the National Research Council's *Projections of Manpower Resources and Research Funds, 1968-72*[3], the largest single Canadian employment market for persons with advanced degrees is formed by the universities themselves. Table VII.4 shows the number of faculty members in various disciplines of marine sciences in the six Canadian universities treated in Figure VII.3, plus Laval. The National Research Council document[4] quotes a figure of 13 per cent per year as the present rate of growth of university faculty. Thus the demand from these six universities alone may call for five new faculty members per year. However, the 82 marine biologists who are now in the graduate schools should yield about 18 graduates per year. Thus unless other universities not included, in this list are falling very far short of producing enough graduates to satisfy their own growth, even a university growth of 13 per cent per year is insufficient to absorb these students. That 13 per cent

[1]Projections of manpower resources and research funds, 1968-72. National Research Council, 1969.

[2]Jackson, R.W., D.W. Henderson, and B. Leung. Background studies in science policy: projections of R&D manpower and expenditures. Science Council of Canada, Special Study No. 6. 1969.

[3]National Research Council, *op. cit.*

[4]*Ibid.*

Table VII.4–Professional Manpower in Marine Science and Technology in the Universities (Estimates for 1968-69)

Discipline	U.B.C.	Dal.	McGill	S.F.U.	U.Vic.	Guelph	Laval	Memorial	Total
Physics	7		4						11
Biological Oceanography and Fisheries	4[a]	6[c]	3	2	1	1	2		19
"Classical" Marine Biology	4[b]	1[d]	8[e]	3	7	4	1	9	37
Chemical Oceanography	1	1							2
Geochemistry			1						1
Geology and Geophysics	3	2	1						6
Engineering		1					1		2
Total	**19**	**11**	**17**	**5**	**8**	**5**	**4**	**9**	**78**

[a]Includes 1 Department of Botany.
[b]Includes 3 in Institute of Fisheries and Department of Zoology.
[c]Includes 2 from Department of Biology.
[d]Includes 1 from Department of Biology.
[e]Includes 2 from Department of Zoology.

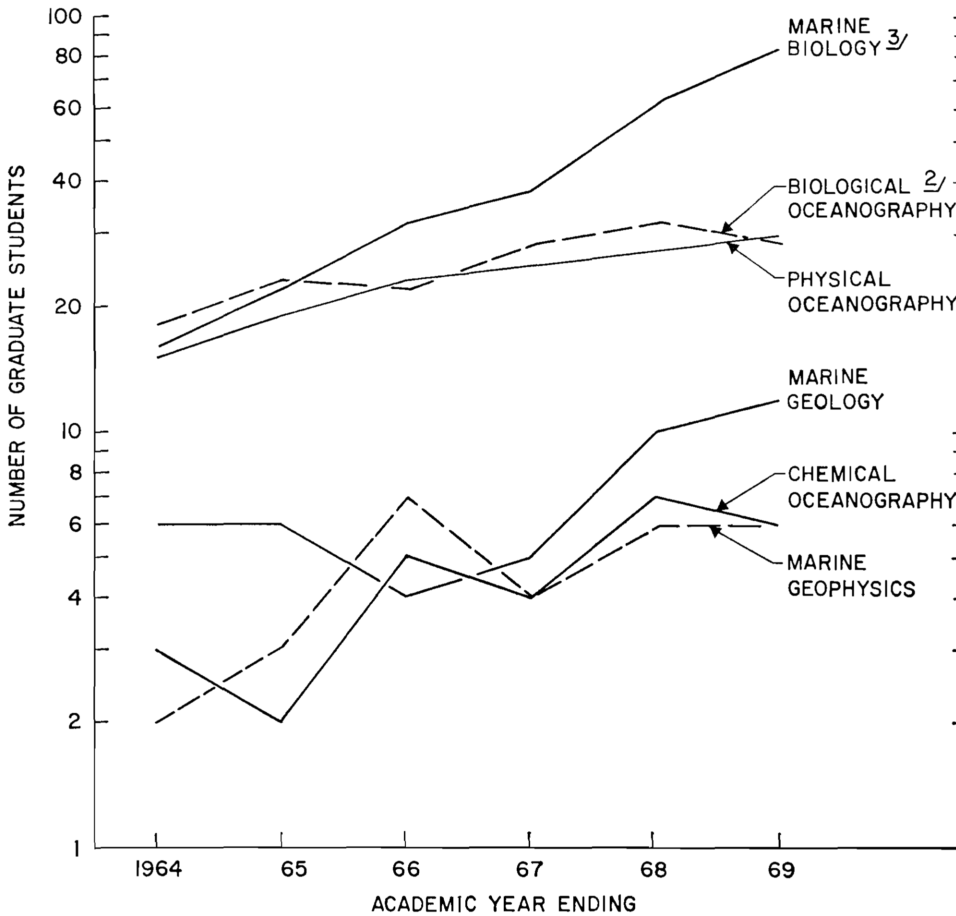
growth itself cannot be sustained. Indeed it is doubtful if it will occur in 1970-71 or ever again. The slope of the Marine Biology curve in Figure VII.3 corresponds to a growth of 35 per cent per year. Obviously, such growth *must* be curbed.

(The numbers quoted in the above discussion are imprecise because of the non-uniform nature of the data at our disposal. Nevertheless, the overall picture which emerges cannot be far wrong.)

Although the growth of these graduate schools in marine biology must be reduced very sharply, and it is difficult to see how even the present number of graduates can all be *professionally* employed, we do not contend that this number is absolutely too large. The general upgrading of the educational level of Canadians can continue. It would not be a bad thing if large numbers of the new recruits into high school teaching had Ph.D.s in science. It can even be argued that the rigours of a scientific training have great cultural value, and that it would not be a bad thing if salesmen and green grocers had M.Sc.s and Ph.D.s in science. However, the financial cost to society of this kind of education is very great, and it is doubtful if we can afford to be so profligate now or in the foreseeable future. Also the future career of a student *should* have some impact on the kind of education he receives. There should be a difference between the nature of education leading to higher degrees for a man proposing to go into high school teaching and another hoping to engage in research.

As we see it, a far larger proportion of marine biologists must be trained as ecologists, in the most modern and quantitative sense in which that word is used. Unfortunately, in Canada this field is often interpreted to comprehend primarily the natural history aspects, involving extensive survey and collecting of animals, their taxonomy, and to a certain extent, their physiological responses to certain environmental variables. There is a need for some of these latter specialties to conduct formal background surveys, staff museums, and engage in high school teaching. But present training programs overemphasize them simply because many of the professors are so oriented. A very significant shift in emphasis towards the ecologist with a sound background training in the mathematical, physical and chemical aspects is indicated for our graduate schools. In Canada the necessarily interdisciplinary aspects of this modernization of marine ecology and fisheries will be most readily developed in the two Institutes of Oceanography and the biology departments directly associated with them. They are the ones in the best position to offer interdisciplinary programs, partly because of the wide

Figure VII.3–Graduate Student Enrolment in Marine Science[1]



[1]Selected universities:
a) Institute of Oceanography, U.B.C.
b) Institute of Oceanography, Dalhousie
c) Marine Science Centre, McGill
d) University of Victoria
e) Simon Fraser University
f) Guelph University.
[2]From the two institutes (i.e. (a) and (b)).
[3]From the other four universities.

range of expertise they themselves contain, and partly through their association with the larger government laboratories of oceanography. In Arctic biology, McGill is in a similarly advantageous position.

There is little doubt in our minds that a higher proportion of marine biology support should be directed through these universities.

There *should* be a demand by governments at all levels and from industries for people competent to undertake anti-pollution problems. Little such demand now seems evident, especially in industry, but this may be because there is virtually no supply in sight. To use an industrial analogy: production must be for some market, but it is not unknown for industry to create markets by advertising. It may be necessary to point out to various levels of government and to industry that they have a need for people competent to study pollution problems.

If, as we expect, concern about pollution remains high, the cost of pollution control will become a significant portion of total industrial costs. If we are to meet our national responsibilities squarely, we must anticipate a situation in which ecologists employed by governments, as well as by private bodies concerned with conservation, will be pressing for more stringent regulations. On its side, industry, even if it is not made responsible for unforeseen "ecological" effects of pollution, will still need to have its own experts who can continually question and test the validity of regulations they are required to follow–they need ecologists too! Since opposition is the abrasive upon which ideas are polished, we should not decry the debate that this situation will generate. It will advance knowledge more rapidly than anything else; it is to be encouraged. The universities must prepare the protagonists.

The marine biological side of the biology picture seems to indicate dangers of over-supply of graduates. Since Canadian universities are unaccustomed to this situation, we have considered it to be worth examining at some length.

In the other fields, demand, as we project it in Table VII.2, exceeds presently available supply.

Physics

Comparison of Tables VII.1 and VII.2 shows a requirement of about 300 physicists and engineers for the government laboratories in the next decade. The Canadian Ocean Development Corporation would require about 50 more. It is to be expected that between one third and one half of these will be physicists, say 150. Replacement of attrition may call for another 50 or so. Thus there seems to be demand for about 20 per year, exclusive of any demand by the universities themselves. This figure also fails to account for the demand for physicists to work on limnological problems.

Figure VII.3 shows the presence in 1969 of 30 graduate students of physical oceanography in the universities–double the number in 1964–corresponding to 15 per cent per year growth rate. Thus while the present output of graduates in physical oceanography is significantly below demand, the growth rate is large, and if it is sustained to the end of the decade, supply and demand should be approaching equality. We therefore do *not* suggest any emergency measures to increase the output of physical oceanographers, but rather a continuation of the present vigorous growth rate for another ten years. A growth rate of 15 per cent per year has a doubling time of five years. As we have taken pains to point out, it should not continue for long. Toward the end of the 1970s, the universities will have to anticipate reduction in the growth rate of physical oceanography.

No matter what policy is followed by the universities, there will be a shortfall in the number of physical oceanographers relative to the demand for the next several years. It is our belief that there is no need to panic over this shortfall. It need only be recalled that of the 90 or so physicists now practising marine physics, only a handful have had formal graduate training in the field. It is widely recognized that this formal training is very valuable, and many government laboratories have sent personnel already on their staffs back to the universities to get it.[1] However, it is by no means essential.

The shortfall can be made up in two ways: by bringing in personnel from abroad, and by employing persons without any special marine background. Both methods have been used in the past, and both can be used in the future. We should prefer to see rather more emphasis on the latter. There are several hundred physicists graduated with advanced degrees in Canada every year. If some of the best of these wish to move into the marine field and gain their special knowledge "on the job", they should be encouraged. They will in the long run be more valuable than those with special training in the marine field but with less basic intelligence. To be blunt, we are aware of rather too many of the latter kind graduating from U.S. schools of oceanography.

Biological Oceanography and Fisheries
Almost everything said above about physics can be repeated with respect to the quantitatively trained, ecologically minded biologists. The number needed–perhaps 130 with attrition–is rather lower, and could in fact be approximately achieved with a growth rate of 15 per cent per year, which is slightly faster than that of the last five years. In fact, it is probably wiser to grow somewhat more slowly, and anticipate a level of three rather than four times the present a decade hence.

The principal difference between this biological situation and that of physics is that here the persons graduated with advanced degrees in biology, but outside the speciality, may be less adaptable to the needs than are, say, nuclear physicists to the needs of physical oceanography. The reason for this is weakness in the basic background of mathematics, physics and chemistry displayed by all too many biologists. In many cases, this failing is fortified by a distaste for these subjects–indeed it is often this distaste which led them into biology in the first place. Unfortunately, such people are not of much help in meeting the needs of marine science in the next decade, although there may be some areas–for example in fish psychology and behaviour, needed for advanced design of fishing gear–where they can serve.

In this field, then, more imports of personnel may be needed.

Chemistry and Geochemistry
The demand for chemists and geochemists so much exceeds the supply of specially trained individuals, but is so trivial relative to the hundreds of chemists who graduate every year without this special training, that it is difficult to make a balanced statement. Perhaps what is needed most is to change the *image* of the chemical and geochemical oceanographer. Perhaps a series of seminars offered to chemistry undergraduate societies across Canada would increase the supply of graduate students. If such seminars could demonstrate the complexity of the problems encountered, and the modern methods being employed to solve them, the image of the chemical oceanographer as one who spends his time doing endless titrations could be dispelled.

Geology and Geophysics
The picture in geology and geophysics has much in common with both biological oceanography and physics. The growth picture of demand relative to present supply is very similar to that in biological oceanography, and here also an increase by a factor of 3 over the next decade, followed by a much reduced growth rate, would seem to be implied.

In meeting the shortfall which will occur in the interim, geology and geophysics

[1]Not just Canadian government laboratories. For example, the University of British Columbia has already had one such person each from the United States and from France, and another from France is expected in 1970. Conversely, Canadians have been sent to the United States and to the United Kingdom.

have more in common with physics than with biology, and those with training outside of the marine field should prove fairly readily adaptable.

Engineering

Of all the fields treated in this chapter, we consider engineering the most difficult to deal with. Despite the fact that there is no specialized training for oceanologists offered in Canada, we find some 80 or 90 engineers working in this field in the federal government laboratories and an unknown, but probably much larger, number working in industry. There are also more than 100 professionals in the Department of Public Works concerned with coastal engineering, and the more than 200 professionals in the Department of National Defence concerned with ship design who were noted in association with Table VII.1. We anticipate that the next decade will demand about a threefold increase–perhaps more–of such people. Most of this increase will be in the industry. Thus there is clearly a demand for oceanologists–probably for more than the universities can give special training to in the next few years. The question we are unable to answer is: What should be the nature of this training? We believe that the answer to this will have to come from the industry. Thus we welcome, for example, the initiative of the Dean of Applied Science at the University of British Columbia, in drawing industry representatives into even the earliest discussions aimed at establishing postgraduate training in oceanology.

As we have stated in Chapter VI, we believe that the logical places to start postgraduate instruction in oceanology are in association with the existing Institutes of Oceanography at U.B.C. and at Dalhousie. However, if the field grows at the pace which we anticipate, there may, in a very few years, be a need for some expansion in other places. Laval and McGill are logical candidates for a fairly early move into this area.

Financing of University Research

Table VII.5 displays the sources of funds used by the six universities of U.B.C., McGill, Dalhousie, Memorial, Guelph, and Victoria to support oceanographic research. Not included is the value of ship time, which is supplied to the universities without charge by government-operating departments under the "ship pool" arrangement. If included, the total would be raised from the $2½ million shown in Table VII.5 to about $4 million.

Some salient points to be drawn from this table are:

1. The National Research Council is the major source of research support.
2. Foreign sources contribute more than do the mission-oriented government departments (apart from ship time).
3. The mission-oriented departments make their contribution almost entirely in the form of ship time.

We believe that there are anomalies in this situation. These are associated with the observation that in practice *virtually all of the marine research being carried*

Table VII.5–Expenditures through the Universities[a] on Marine Science and Technology, Estimates for 1968-69

Source	Approx. Amount, $000	%
University Budget	600	23
NRC Grants & Scholarships	1 500	58
Other Federal Departments	190	7
Other Canadian	55	2
Foreign[b]	250	10
Total	**2 595**	**100**

[a]These are only those universities referred to in Table VII.4.
[b]In U.B.C., McGill, and Dalhousie only.
Note: Foreign sources contribute more than the relevance-oriented departments.
"Other Canadian" includes provincial grant scholarships, industry and some small private donations.

out by these university groups is in fact mission oriented. Indeed, both the problems studied and the methods used are very frequently the same as those in the mission-oriented government laboratories. The chief difference is that the government laboratories can deal with questions involving longer time scales than are suitable for university research.

The National Research Council should continue to be the principal source of funds for research which is justified on the basis of excellence alone. There is a small minority of researchers whose work is of such quality that the question of relevance hardly arises, and where it does, there are few competent to judge it.

The great majority of university research workers, however, are not *that* good. For this majority, the relevance of their work ought to be absolutely central to the level at which it should be supported. This is not to say that relevant research cannot also be excellent. As we take pains to point out in Chapter VI, some of it is! But we do believe that some research should be supported primarily because it is relevant. This relevance is best judged by the mission-oriented departments, which are sensitive to the shifts in direction of government policy. We therefore contend that a far larger proportion of the support for university research should come from these departments in the form of grants and contracts. It is ironic that their present support, in the form of ship time, gives these mission-oriented departments very little chance to influence the direction of university research, the financial support for which has been determined by others and based on quite different criteria.

Between grants and contracts, we favour grants. The university researcher may be doing mission-oriented research, but he is *not* in a mission-oriented department. He must be allowed to behave like the university researcher that he is. In practice this means that he must have a great deal of flexibility. If, in the course of a research program directed towards a certain goal, he finds that some new and more promising path has opened up, leading to a quite different goal, he should be allowed to follow that path. This should be possible even if the new goal is associated with an entirely different mission. He will, of course, have to take his chances on finding support from the department responsible for this new mission (or on the basis of excellence), but he should not be required to beat his way to the old goal despite the new trend of his interests.

Appendices

Appendix A

A. Definitions

Marine sciences encompass the study of the oceans, their contents and their boundaries. Included among the various fields are:

1. physical oceanography and physics of sea water and ice;
2. chemical oceanography and marine chemistry;
3. biological oceanography and marine biology (including marine fisheries);
4. geological oceanography and marine geology;
5. marine geophysics and geochemistry;
6. air-sea interaction studies;
7. hydrodynamics related to the ocean;
8. hydrography;
9. shoreline dynamics.

Marine technology for the purposes of this study concerns devices and techniques for

a) the study of the marine sciences;

b) the exploration and exploitation of marine resources*;

c) engineering for the marine environment.

B. Terms of Reference

1. National Objectives in Marine Sciences and Technology

Considering the present and potential importance of marine sciences and resources to the economy of Canada, and the potential socio-economic benefits which may arise, the study should:

a) identify rational objectives in marine sciences and technology and assess these goals in the context of broader national and scientific objectives;

b) identify specific areas where Canada could play a significant or distinctive role. These could arise, for example, from Canada's particular geography and climate, from the need to deal with specific

*Marine resources include those of the subsoil, bottom and superjacent waters of the Continental Shelf, slope and deep ocean as well as the recreational potential of the marine environment.

Note: While limnology and hydrology and bedrock geology are not included in the above definition, the study will go into these areas as far as is necessary for the sake of completeness.

problems such as ice, pollution and navigation, and from the opportunities provided by the existing scientific and industrial expertise.

c) assess the contribution of marine sciences and technology relating to:

i. resources of the shelf, slope and deep ocean

ii. foreign relations

iii. external aid

iv. Canadian sovereignty

v. oceanographic aspects of defence

vi. special legal rights

vii. scientific co-operation and exchange of information

viii. problems of transportation and navigation.

2. Review of the Present Status

a) To review present programs in marine sciences and technology in Canada and relate this activity to the national objectives.

b) To assess the present effort (including funding) in view of the national objectives.

c) To reach conclusions concerning the desirability, feasibility, and method of integrating existing and potential programs in a co-ordinated national effort.

3. Priorities

To identify priorities, related to national objectives in marine sciences and technology.

4. Requirements

a) To specify the kinds of governmental (including defence), academic, and industrial organizations necessary to place Canada in the best possible position to obtain knowledge related to marine resources and to develop the marine services, exploitation and instrumentation industries.

b) To forecast the requirements for trained personnel for the next ten years in view of the identified priorities.

c) To ascertain the requirements for institutions needed to train this personnel.

d) To determine the level of funding necessary to meet national objectives.

e) To outline a mechanism by which the national research development and innovative* effort could be appropriately managed, including co-ordination among industries, universities and governments.

*The definitions of research (basic and applied), development and innovation are given below. These definitions were outlined in Science Council Report No 4, *Towards a National Science Policy for Canada*, October, 1968.

1. Basic or Fundamental Research which is a generalized search for new knowledge without specific application in mind, and which is one of man's crowning cultural achievements. Any piece of basic research is judged on the contributions which it makes to the conceptual development of science.

2. Applied Research is the search for new knowledge to provide a solution to a specific problem which is defined at the outset of the research program. It differs radically from basic research, not in methods of scope, but in motivation. Applied research programs must be judged by their relevance to the preselected objective.

3. Development is really a final stage of applied research which is most clearly seen in the evolution of new goods or services, It is a costly activity inasmuch as the building of prototypes, the construction of pilot-plants or the conduct of full-scale trials are costly undertakings.

4. Innovation is the practical implementation of the results of research and development to provide new or improved goods or services. Innovation is often a capital-intensive activity since new production facilities are often required. In deciding to undertake programs of development and innovation, the expenditures foreseen must be weighed against the probability of achieving economic gain or social benefit.

These activities have no distinct boundaries, but merge into each other and are part of what could be considered a "spectrum of scientific activities".

Appendix B

Estimates of Some Project Costs for the Canadian Ocean Development Corporation

	Costs (millions of dollars)	Average Annual Cost
1. Underwater Drilling Program (5-year duration)		
Subsystems Development & Construction:		
Manned underwater operating base	20	
Ballast system	5	
Propulsion system	5	
Docking-mooring system	5	
Drilling methodology	10	
Drilling system	5	
Drilling machinery development	5	
Hyperbaric interface systems	5	
	60	
Average Annual Cost		**12.0**
2. Underwater Power Supplies (10-year duration)		
(Co-operation with Atomic Energy Canada Ltd.)		
Under-ice mobile nuclear packages (shared cost–AECL)	35	
Umbilical system	5	
Underwater transmission cable & converter system–land base	5	
Seabed systems–liquid 0_2 & fuel systems	10	
Snorkel system	5	
	60	
Average Annual Cost		**6.0**
3. Underwater Well-head Completion System–Deep Water (5-year duration)		
Comparison of systems & construction	20	
Submersible service development	10	
Manipulator systems	5	
	35	
Average Annual Cost		**7.0**
4. Pollution Control & Recovery Program (continuing)		
Equipment development		
Average Annual Cost		**2.0**
5. Establishment of Equipment & Pressure Testing Facilities (5 years)		
(c.f. U.S. Florida facility–$12 million)		
Average Annual Cost		**3.0**

	Costs (millions of dollars)	Average Annual Cost
6. Arctic Geophysical Survey–Under-ice (5 years)		
Equipment development	10	
Survey ship & submersible costs	15	
	25	
Average Annual Cost		**5.0**
7. Cold Weather Engineering for Surface Support (5 years)		
Development of equipment	10	
Logistics Support	5	
	15	
Average Annual Cost		**3.0**
8. Environmental Prediction & Interpretation Services (5 years)		
Equipment construction & placement	3	
Computer services	1.5	
Special surveys, 5/yr. @ $100 000	2.5	
Consulting contracts in 5 areas	5	
	12	
Average Annual Cost		**2.4**
9. Fisheries Information & Fishing Strategy Service (5 years)		
Equipment development and construction	5	
Operations research trials	1.5	
Computer services	1.0	
Contracts for consulting staff	1.0	
	8.5	
Average Annual Cost		**1.7**
10. Fishing Vessel Automation (5 years)		
Equipment & gear development	5	
Ship development & construction	2	
Average Annual Cost	7	**1.4**
11. Estuarine R & D for Fish & Molluscan Culture (5 years)		
Staff, 10 man-years	1	
Rental & construction of facilities	1.5	
Average Annual Cost	2.5	**0.5**
12. Technology Transfer & Education Programs (continuing)		
Exchange staff salaries & support (30/yr.) @ $40 000	1.2	
Scholarships & student stipends (40/yr.) @ $5 000	.2	
	1.4	
Average Annual Cost		**1.4**

	Costs (millions of dollars)	Average Annual Cost
13. Special Instrument Development (continuing)		
Each Instrument:		
1½ prof. @ $20 000 $ 30 G		
3 support @ $10 000 30		
Equipment costs 35		
Overhead 5		
Total/instrument 100 G		
Suppose 10 instruments/yr. @ $100 000 = $1.0 million		
Average Annual Cost		**1.0**
14. Information Services (continuing)		
Library staff (included in staff operating budget)		
Aquisitions of books & equipment $ 250 000/yr.		
Advertising budget 350 000/yr.		
Computer service 250 000		
Publications & marketing 250 000		
Management consultations 400 000		
Total/yr. $ 1 500 000		
Average Annual Cost		**1.5**
Total		**47.9**

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