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FUTURE OF U.S. OCEANOGRAPHY[1]

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ABSTRACT

In spite of the risk of trying to predict the future, several areas of marine research appear particularly promising for research opportunities. These include: increasing the yield of animal protein from the ocean; deriving energy and mineral resources from the ocean; controlling pollution; predicting climate; and understanding the role of the oceans both as a sink and as a source of elements. Perhaps even more important than these general research topics is that several key factors may override and perhaps control the directions of marine scientific research in the coming decade. These factors include:

- Law of the Sea restrictions, implications, and opportunities;
- Role of marine science in U.S. foreign policy;
- U.S. budgetary changes and inflation;
- Development of large-scale oceanographic programs;
- Increased emphasis on applied programs, especially in the coastal zone.

Not only the currently promising areas of marine research but also these potentially overriding research-related factors may offer increased opportunities and encouragement for cooperative work with developing countries in marine science.

INTRODUCTION

There is considerable risk in trying to predict the future[2] for any field of endeavor, and this is especially true in such a

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[2]As I reread (April 1981) this article, about a year after it was written, I am startled by the changes in marine science that may result from a new administration in Washington, D.C. There has been a change in our focus at the United Nations Law of the Sea Conference and a possible end to the National Coastal Zone Management Program, the National Sea Grant Program, and the National Oceanic Satellite System (NOSS). Nevertheless, I have decided to leave the paper as it was, perhaps making it a vivid example of the difficulty of trying to predict the future.

multidisiplinary science as oceanography. However, recent studies and an appreciation of U.S. needs for the future suggest specific questions for marine scientific research. These include how to increase our animal protein harvest from the ocean, how to extract energy and minerals from the ocean, how to control ocean pollution, how to forecast climate, and how to use the oceans as a sink for disposal and perhaps as a source for some elements. Several of these areas of research will be especially appealing for collaborative work with developing countries.

In my opinion their are several key factors emerging in the United States and elsewhere that will strongly influence and even control some aspects of marine science in the 1980s. The more important of these factors include:

- Law of the Sea (LOS) restrictions, implications, and opportunities;
- Role of marine science in U.S. foreign policy;
- U.S. budgetary changes and inflation;
- Development of large-scale programs like the Ocean Margin Drilling Program (OMD) and the National Oceanic Satellite System (NOSS); and
- Increased emphasis on applied programs, particularly in the coastal zone (and especially programs directed toward deriving energy from the sea) and the possible designation of the 1980s as the Decade of Ocean Resource Use and Management.

I suggest that these factors will play an important role in driving marine science in the 1980s, and should be considered in speculations about the future. These factors and the types of scientific problems that will develop in the 1980s could lead to increased cooperative work with foreign countries. LOS restrictions and budgetary problems, however, could work against such cooperative efforts, unless special programs or emphasis are developed within areas of the U.S. marine science community or funding agencies. Implicit in these remarks is that U.S. oceanographers may have a decreasing role in the development of their science.

GENERAL COMMENTS

A few generalizations are necessary before discussing specific points. Oceanography (or marine science) is a mixture of various natural sciences directed toward the study of the ocean. Traditionally, a marine scientist is expert in one, or part of one, of four or five divisions that make up the total field, i.e., biological oceanography, physical oceanography, chemical oceanography, geology or geophysical oceanography, and ocean engineering. A marine scientist's education, usually to the Ph.D. level, generally has followed one of two pathways:

1. Training in a specific scientific discipline (e.g., biology) and special emphasis on a marine aspect of that discipline, or

2. Some training in all fields of oceanography, but with a specialization in one division.

The latter probably produces the more general oceanographer, while the former more likely produces a specialist. However, these differences can be muted by many individual factors, including experience.

Future training of U.S. marine scientists probably will continue to follow the format outlined above, although increasing emphasis on applied research and specific, long-term programs indicates that different types of training might be appropriate. For example, if the 1980s are going to focus on ocean resources and their management, professionals will be needed in government and elsewhere with scientific training and with business, legal, or managerial experience. In addition, countries just beginning marine scientific efforts probably cannot afford the luxury of large numbers of highly trained experts, but rather will need more generally trained oceanographers as well as the scientific and managerial types mentioned above. These needs could lead to new marine-education efforts.

In recent years, individuals from social sciences (anthropology, and economics, for examples) have become increasingly interested in ocean-related problems. This interest has led to the emergence of a new, rather poorly defined field, commonly called marine policy, that has attracted some practicing oceanographers. Considering the trend toward applied studies of the oceans, this new field might be a factor in the future development of marine science.

"Interdisciplinary studies" is a common phrase used in proposing oceanographic research. An interdisciplinary approach becomes a necessity when the uses of the ocean are considered, especially in coastal regions. This approach is necessary because the problems associated with ocean use and the solutions and ramifications of those problems are too broad to be handled by individuals or groups from one discipline alone.

An important aspect of the future of marine studies is development of new technolgies that will allow long-term (months to years) in situ monitoring of oceanographic phenomena such as bottom currents and sediment movement. These technologies, coupled with more sophisticated satellite observations (combined with ground truth), and experiments using the ocean will give oceanographers the ability to consider problems that only a few years ago were beyond their scientific capabilities. The new technologies will have a high cost and probably will not be available to all institutions, groups, or countries, although the opportunity for sharing or cooperative work exists.

It should be emphasized that "breakthroughs" in marine science can come from many directions. These include new instrumentation and technology, interdisciplinary studies sometimes involving fields not previously associated with the ocean, new studies in unique areas, new approaches to old problems often motivated by economic or social factors, and luck. Recent findings, such the discovery of hydrothermal vents in the Galapagos Rift, suggest that the ocean still holds surprises that might change or influence certain fields of oceanography.

Ocean science on almost any level is expensive, and only a few academic institutions are able to consider most or all of the five major disciplines of oceanography. On the other hand, at least eight federal agencies have objectives in the ocean: Coast Guard, Environmental Protection Agency, Department of Energy, National Aeronautics and Space Administration, Department of the Navy, National Oceanic and Atmospheric Administration, National Science Foundation, and the Department of the Interior, through the U.S. Geological Survey and the Bureau of Land Management. Within the U.S. marine research effort, there are three principal groups of players.

1. Federal Agencies. These principally include the National Oceanic and Atmospheric Administration (Commerce) and the U.S. Geological Survey (Interior). Their efforts are mainly regulatory, and surveys are common operations, although each has in-house programs that consider both basic and applied resarch. Both organizations also subcontract (mainly USGS) or award grants for research (Sea Grant, part of NOAA). The National Science Foundation and the Office of Naval Resarch are the other major funders of marine research; the former supports mainly basic research.

2. Research Institutions and Universities. These organizations perform much of the basic marine research in the United States and are funded to a large degree by federal agencies. However, they also do a significant amount of applied research as indicated by the large number of Sea Grant-supported activities at U.S. universities.

3. Industry. Industry often focuses on practical application of marine science (for example, extraction of ocean resources) but sometimes funds basic or applied research, especially for environmental studies, at universities.

In evaluating the future, it is, of course, important to consider the past. During the past decade and a half, a considerable amount of U.S. legislation has been passed that has influenced the directions of marine scientific research and its funding. Examples are:

- Establishment of the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA).
- Passage of the Federal Water Pollution Control Act Amendments of 1972, the Marine Mammal Protection Act of 1972, the Marine

Protection Research and Sanctuaries Act of 1972, the National Sea Grant College and Program Act of 1966, the Coastal Zone Management Act of 1972, National Ocean Pollution Research and Development and Monitoring Planning Act of 1978, and the Fishery Conservation and Management Act of 1976, among other federal laws.

In spite of these acts, there is a common, and probably correct, view that the federal government lacks a clear policy toward ocean-related activities. The National Advisory Committee on Oceans and Atmosphere (NACOA) has stressed this point and has said that in spite of the extensive federal activity, the result is disjointed and lacks a cohesive purpose.[3]

Before discussing some important, specific scientific areas, a discussion is presented of the five key factors, mentioned earlier, that will have a large influence on marine science in the 1980s.

KEY FACTORS THAT WILL INFLUENCE MARINE SCIENCE IN THE EIGHTIES

Law of the Sea Restrictions, Implications, and Opportunities[4]

The past freedom to conduct marine scientific research in most of the ocean has allowed U.S. scientists to make major marine scientific discoveries. On the other hand, it may be unrealistic to assume that the more restrained consent conditions to be imposed as a result of the present Law of the Sea (LOS) negotiations will reduce the rate of scientific breakthroughs; more likely they will determine the geographic regions of discovery. The Law of the Sea will immediately affect how individual scientists maintain the style of their research. Most U.S. marine scientists have little interest in the process of negotiating permission for entering foreign waters and, in any case, might be hesitant to meet the LOS conditions necessary to get such permission. Pressures for promotions, funding limitations, etc., may preclude scientists from developing training or assistance programs with foreign countries. Thus a probable initial effect of LOS is that many marine scientists will avoid working in those regions where difficulty is anticipated and will focus instead on the deep sea or on U.S. waters. There is some evidence to suggest that this has already happened; Dr. Dirk Frankenburg, then division director of ocean sciences of the NSF Oceanographic Section, indicated in February 1980 that none of the five then pending proposals for research projects similar to those carried out under the International Decade of Ocean Exploration involved work in foreign waters. In addition, he

[3]Letter dated 31 March 1980 from Evelyn F. Murphy, chairman of NACOA, to various individuals concerned with marine science.

[4]See "Ocean Science, Law of the Sea, and Marine Technical Assistance," by John Byrne.

noted that many regular NSF proposals for work in foreign waters had "fall-back positions" in case difficulties arose in obtaining permission. Funding agencies, in general, seem to be taking no action or consideration toward research changes because of LOS problems. By avoiding difficult regions, we make our worst fears about the LOS come true, unfortunately, without really testing or stressing the LOS articles on marine scientific research. Alternatively, it may be that those first few countries that open their waters to U.S. scientists will find many takers waiting. The recent NOAA-sponsored oceanographc cruise to the People's Republic of China (even though it had several restrictions) may be an early example of this.

The LOS negotiations and their wide publicity may have other, more subtle effects than the potential restraint of scientific research in the ocean. The LOS negotiations already may be adversely affecting numbers of new students in and the interest toward the field of marine science. Several institutions have noted a drop in the number of applicants, although it is hard to establish the causes at this time. If this trend continues, U.S. institutions may make more opportunities available for foreign students.

It is fair to say that there is potential for good to come out of the marine scientific research articles in the LOS. Specifically, they should inspire less-developed coastal countries to become more concerned about their adjacent waters and perhaps encourage cooperative research with other countries. Our understanding of the ocean would benefit by having other countries develop a scientific interest in the ocean.

Potential Role of Marine Science in U.S. Foreign Policy

For various reasons, including an attempt to improve on the Informal Composite Negotiating Text (ICNT) resulting from the Law of the Sea conference, several types of cooperative arrangements are being or have been negotiated recently with foreign coutries. NOAA has been especially active in this capacity, having recently negotiated a bilateral agreement with China and presently discussing possiblities with Venezuela and Ecuador. The U.S. State Department has had discussions with several other countries. The arrangements, often driven by nonscientific considerations, should offer some opportunties for cooperative scientific research with developing countries, but they do have the potential for difficulties and high costs. This topic is beyond the scope of this paper but is treated in a separate study by a subgroup of FOSTG (Freedom of Ocean Science Task Group) of the Ocean Policy Committee of the National Research Council's Commission on International Relations.

In the future, some aspects of international marine science may be driven more by national and political implications, economics, and diplomacy than by the science. Bilateral and similar arrangements,

involving technical assistance and training, could become a common modus operandi of marine science in the future.

U.S. Budgetary Changes and Inflation: The Costs of Doing Science

Marine research is obviously influenced by finances. Recent increases in the cost of fuel are posing problems for the academic fleet, the National Ocean Survey (the ship operations group of NOAA), and naval research vessels. At the time of this writing, all these organizations are making cutbacks in their operations. The potential of the fuel-cost problem is considerable and may severely limit or restrict distant water operations. It seems likely that even closer cooperation will be needed within UNOLS (University National Oceanographic Laboratory System) and with NOAA and the Navy to ensure the full and efficient use of ships that are operating.

The problems of inflation reach elsewhere. In the past, many institutions grew roughly in proportion to the funding they received. However, with the increase in inflation beginning in about 1978, growth, if any, often correlates better with a constant dollar factor. As costs and salaries rise to keep pace with inflation, research and support funding fall behind in real dollars, and some adjustments must be made. These adjustments can include:

- closing or reducing the size and scope of oceanography departments and institutions;
- reducing ship operations and delaying replacements of older ships; and
- supporting very broad consensus-like studies and specific applied studies with short-term results.

Financial exigencies could encourage closer and longer-range cooperative agreements with foreign countries, especially if the agreements involved financial support arrangements. In addition, the opportunity to use foreign research vessels could become extremely appealing as ship time becomes more expensive and harder to obtain in the United States.

Large-Scale Programs

Certainly one major component of U.S. marine science in the 1980s will be large-scale (many disiplines, many institutions, many agencies) scientific programs. Three of these programs are fairly well started (although still vunerable to budget changes): Ocean Margin Drilling (OMD), National Oceanic Satellite System (NOSS), and the National Climate Program; a fourth program, directed toward deriving energy from the ocean, seems forthcoming.

The OMD is a very sophisticated and expensive project. Present plans are to drill 15 holes between 1984 and 1989 mainly on passive continental margins (about 12 holes) with the remainder for active margins, paleoenvironment studies, and ocean crust studies. The Glomar Explorer will be refitted and equipped with a riser and complete well-control facilities for blowout prevention. This vessel will replace the highly successful Glomar Challenger. When modified, the Explorer will be able to drill with risers in waters up to 4,000 meters deep and penetrate 6,000 meters into the seafloor. The total cost of the ten-year project is estimated at $700 million. Several U.S. oil companies and foreign countries are expected to participate. Plans for this and other projects have been discussed by a wide group of international geologists and geophysicists from many nations over several years.[5]

NOSS is a cooperative effort of the U.S. Department of Energy, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration. Past studies have shown the value of satellite observations in oceanographic research[6] and in operations activities. NOSS is planning a demonstration of the feasibility of measuring surface wind velocity, significant wave height, sea-surface temperature, sea ice conditions, current measurements, and chlorophyll and other optical characteristics of the water column. NOSS information will be of considerable use to the oceanographic community as well as to the federal agencies. NOAA, for example, will use the information to improve its weather forecasting ability, and the Navy will use it for such applications as ship routing and global ocean data forecasting. NOSS will provide information for marine transporation, offshore mining, fishing and exploration activities, as well as providing scientific information about sea-surface dynamics. Conferences were held around the country to inform potential users of NOSS data and to develop participation in the NOSS program.

The third large program now under way is the National Climate Program, a five-year interagency effort coordinated by NOAA. One focus of this program will be to evaluate the effect of increasing levels of atmospheric CO_2 on global climate. In addition to NOSS and the National Climate Program, other large programs concerning marine pollution (a five-year plan is being developed) and seabed mining will be coordinated by NOAA. Although NOAA's budget has tripled in the last decade (to $800 million) and its responsibilities

[5]The Ocean Crustal Dynamics Program Plan for the 1980's. Joint Oceanographic Institutions (JOI), Inc., is another large-scale earth science project probably with less chance of success than OMD.

[6]See "Technology Transfer to Developing Countries: Future Use of Remote Sensing in Biological Marine Resource Development," by V. Klemas.

have expanded, the size of the agency's staff has increased by only 2 percent. Thus, it is possible that in future years, even more extramural work will be sponsored by NOAA.

The broad scope of these current large-scale programs and their international aspects suggest that they could also be useful in developing cooperation in other marine activities between U.S. and foreign scientists on state-to-state or on individual levels.

Increased Emphasis on Applied Programs and Possible Designation of the 1980's as the Decade of Ocean Resource Use and Management

In 1979, a group of 12 U.S. Senators and 40 Representatives sent a letter to President Carter urging increased emphasis on ocean resources and their potential. They requested that the 1980s be designated the Decade of Ocean Resource Use and Management. The objective in part would be an extension of work done by the International Decade of Ocean Exploration (IDOE) in the 1970s, but with more emphasis on resources, especially energy. At this writing, the letter has not received a significant response, although NACOA has been asked by the Executive Office to consider what such a designation would mean.

I have assumed in writing this document that a trend toward more applied research is developing in the United States. Evidence for this view is the types of large-scale programs being developed (OMD, NOSS, National Climate Program); increased activities of NOAA; growth and success of the Sea Grant Program; general statements of members of Congress toward applied, especially energy-related, marine research (see, for example, Sea Technology, 21:35-43, April 1980); and my own experience and conversations with colleagues. Other topics of applied research that should or will be stressed in the 1980s are deep-sea mining of manganese nodules; ocean thermal energy conversion (OTEC); disposal of waste products in shallow water; the possibility of nuclear waste disposal in the deep sea; and satellite studies of coastal zone processes. The trend toward increased extramural funding of projects by NOAA, the relative decline of ONR as a funding source (recent events suggest the possibility of increased military growth that could affect ONR), and the addition of several coastal-zone-type vessels to the UNOLS fleet also suggest increased coastal and applied research in coming years. It should also be mentioned that the United States will gain a considerable amount of marine territory through the LOS negotiations.

If this projection of increased study of the U.S. coastal zone (i.e., our EEZ) is correct, it follows that there may be a similar increasing interest among U.S. scientists and institutions in working in the EEZs of foreign countries. Techniques, skills, and educational opportunties refined in U.S. work would make an appealing package for cooperative efforts, especially with LDCs.

SPECIFIC SCIENTIFIC AREAS OF CONCERN FOR THE 1980s

This paper is not the first attempt at prediction of marine science in the 1980s. Several reports and documents have focused on all or part of the question. Probably the most comprehensive of these reports is The Continuing Quest: Large-Scale Ocean Science for the Future,[7] which looked at future IDOE-type programs and drew upon the results of several workshops organized by the National Science Foundation. John V. Byrne also prepared a paper[8] for the Ocean Policy Committee's 1979 Workshop on Coordination of International Oceanographic Research, in which he attempted predictions.

It seems most constructive for this short note to list briefly what might be the major areas of emphasis in marine science in coming years. The Continuing Quest has been a major source for my information. Several key areas for marine research are obvious. These research areas, although often involving fundamental scientific questions, are relevant to society and to use of the ocean. Among the more important are:

1. Increasing the Harvest of Animal Protein from the Ocean. Important questions include defining the processes that affect the dynamics of fish growth, including climate, pollution, fishing activities, and interactions between various species. Use of new fishing technologies, species (krill, for example), and management techniques (such as, exploiting natural fluctuations in recruitment) are also important aspects.[9]

2. Energy from the Ocean. Increased hydrocarbon production from the continental shelf and slope, exploration of the continental rise, and the study of clathrates as a potential source of natural gas are important to obtaining energy from the oceans. Other marine sources of energy, such as biomass conversion, OTEC,[10] waves, tides, currents, and salinity differences, also will be explored more throughly than in the past.

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[7]Prepared for the National Science Foundation by the Post-IDOE Planning Study Steering Committee of the Ocean Sciences Board, Assembly of Mathematical and Physical Sciences, National Research Council. Available from the National Academy of Sciences, Washington, D.C., 1979.

[8]Within a Crystal Ball: Possible Future Directions of Marine Science and International Implications.

[9]See "World Fisheries and Aquaculture a Decade Hence: One View," by Francis Williams.

[10]See "Ocean Technology and Development," by John Craven.

3. Mineral Resources. Marine sand and gravel is already a multimillion-dollar industry in England, but before it can become a major U.S. industry, environmental and scientific questions must be answered. Many of the same questions must be answered with regard to the mining of manganese nodules. Heavy metal deposits in the Red Sea (which are close to being mined) and the Galapagos region may also be important.

4. Pollution. Marine pollution problems are immense. Especially important are defining the effects of a potential pollutant and knowing its source and rate of introduction, its history and pathways in the environment, its tranport processes and rates, and its ultimate fate.

5. Climate. Air-sea interactions are major factors in determining climate and the development of storms. It is especially important to develop better mechanisms of long- and short-term weather prediction, ways of modifying weather, and an assessment of potential effects of man's activities; for example, the increase in atmospheric carbon dioxide resulting from the burning of fossil fuels.

6. The Oceans as a Sink. The increasing volume of waste products on land coupled with the decrease in available disposal space make the prospect of waste disposal at sea, including disposal of nuclear waste, especially appealing. Important scientific questions such as waste-product interactions with the biological community should be answered before economic considerations become overwhelming.

7. The Oceans as a Source. Recent discoveries from the Galapagos Rift suggest that some chemical elements may be entering the ocean through the volcanic and hydrothermal activity along rift systems, although the implications of this process are relatively unknown.

Areas 1, 2, 4, and to some degree 6 are those that should have the most appeal to developing countries. Energy from the sea--OTEC, for example--would be an especially attractive technology transfer item, especially to energy-poor countries situated in tropical or near-tropical regions adjacent to a water mass having a large vertical range in temperature. The combination of OTEC with an aquaculture-like system could be even more appealing if it becomes economically feasible.

Specific subjects mentioned in The Continuing Quest are the following:

- Physical Oceanography. Estuarine-shelf dynamics, continental shelf dynamics and shelf-ocean coupling, western boundary region dynamics, midocean (interior) dynamics, large-scale atmosphere-ocean coupling

- Biological Oceanography. Climate variability and productivity, physical forcing of species succession, biological interactions among species, trophic-level coupling, community structure, patchiness, recruitment
- Chemical Oceanography. Water-column fluxes and reactions, seafloor fluxes and reactions, fluxes from the continent to the ocean, transient-tracer studies, gas-exchange studies, tracer-injection studies
- Marine Geology and Geophysics. Characteristics and driving mechanisms of the deep lithosphere and asthenosphere, evolution and variability of the ocean crust and upper mantle, structure and evolution of passive continental margins, structure and evolution of convergent-plate margins, diagenesis at depth, the ocean's role in climatic change over the past 150,000 years, and climate over the past 5 million years

Other evaluations of future projects include those of the Ocean Sciences Board, which has recently started a series of discussions on future trends in various fields of marine science. One such meeting[11] in Feburary 1980 on marine chemistry mentioned the role of the oceans in the CO_2 cycle, mathematical models of chemical cycles, thermal midocean vents as sinks rather than sources of chemicals, continued searches for hot spots to better assess their role, research on the biological factors in geochemistry, deep drilling in basalts, and use of natural radionuclides to study ocean processes. Participants in the meeting also considered the need to develop remote and long-term chemical sensors.

In a letter dated 2 April 1980 to various members of the oceanographic community, Mr. Richard Frank, adminstrator of NOAA, indicated several areas of importance for his administration in fulfilling NOAA's long-term oceanic and atmospheric responsibilities. These areas include:

- Oceanic/atmospheric interactions. The data set from the Global Weater Experiment, planned to be made available in 1980, will provide an unprecedented collection of observations that can be used for studies of air/sea interaction. Future experiments should be designed to develop and test predictive models of important phenomena.

- Oceanic heat transport and storage. The climate program is expected to include more studies on interannual changes in heat transport by oceanic currents to polar latitudes and on the storage of heat in oceanic surface layers, which can provide a basis for climate monitoring.

[11]As reported in Ocean Sciences Log, April 1980, No. 13 - an information publication compiled by R.C. Vetter of the Ocean Sciences Board, National Research Council.

- Marine assimilative capacity. NOAA's 5-year plan for study of marine pollution proposes long-term studies of natural ecosystems, the processes of transport, the fates and effects of contaminants, and the development of predictive models to aid in the evaluation and control of marine pollution.

- Coastal water and sediment dynamics. NOAA is proposing new research on coastal circulation and its effect on biological productivity, coastal sediment transport as it affects shore structures and beach stability, and wave and severe-weather sea level variations as a basis for understanding the coastal environment as a site for human activity and technological development.

- Application of remote sensing techniques. With NOAA's increased satellite responsibility, the agency will need refinement of acoustic and satellite remote sensing techniques to assist in the study of oceanic and atmospheric research problems.

Much of NOAA's planned work will be of interest to LDCs, and this agency could become a leader in foreign collaborative research.

In the field of marine policy, considerable progress was made in the 1970s with strong legislation for environmental protection and the development and relative acceptance of the Coastal Zone Management Program. The theme for the 1980s will likely be multiple-use, sustained-yield, ocean resource management,[12] with energy a dominating factor.

CONCLUSIONS

U.S. oceanographers will have some very important marine science questions to consider in the 1980s. The success with which oceanographers deal with these questions will be strongly influenced and perhaps controlled by factors beyond their control: Law of the Sea restrictions, implications, and opportunities; political factors; budgetary changes and inflation; large-scale programs; and trends toward more applied programs, especially in the coastal zone. The developing trend in the United States toward applied oceanographic research, in particular, could increase enthusiasm for working cooperatively with less-developed countries, depending on financial and Law of the Sea constraints.

[12] J.W. Curlin (1980) Ocean policy comes of age: The end of the beginning or the beginning of the end. Sea Technology, 21:11-28 January 1980.

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