New Policy Protocols for Marine Scientific Research: Lessons Learned from Past Case Studies

by

Stephanie Ann Harrington

Submitted to the Department of Ocean Engineering
in partial fulfillment of the requirements for the degree of

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Abstract

A set of policy protocols is developed for marine scientists conducting experiments in the ocean. These protocols are designed to assist researchers in incorporating public input into their research without compromising the integrity of the science in this new era of intense public scrutiny.

The foundation for these protocols is established through an analysis of the relevant national and international legislation and a series of case studies of oceanographic research. Through this analysis, two major transitions in the political framework of marine scientific research become apparent: 1) an "internationalization" of oceanography in the 1970s, and 2) a "democratization" of oceanography in the 1990s. The examination of the legislation reveals the origin of these transitions in the evolution of the national and international political climates that reflect the constant advances in the understanding of the ocean environment. The case studies provide concrete examples of research that has been executed within the framework of the transitions: 1) Deep-sea drilling started in the 1950s in the U.S. and became an international effort in the 1970s because of various external pressures; 2) Acoustic tomography includes the benchmark example of public scrutiny in marine science and demonstrates the potential for severe negative consequences if scientists are not prepared for public involvement; and 3) An experiment in CO_2 sequestration is currently in the planning stages and provides an opportunity to apply the new policy protocols in an attempt to incorporate public input while maintaining appropriate scientific methods and standards.

A condensed version of the policy protocols for marine scientific experimentation illustrates the basic approach to public involvement:

1) Establish a broad support base within the scientific community.
2) Identify stakeholders and engage in appropriate public outreach.
3) Expect inefficiencies and plan accordingly.
4) Conduct research in a transparent fashion throughout all of the phases of research - planning, implementation, monitoring, and distribution of results.
5) Maintain management flexibility capable of working with change and the relevant interest groups.

Thesis Supervisor: Judith T. Kildow
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Contents

Chapter 1

Introduction

As marine science and policy in the United States have evolved over the past fifty years, they have become more and more interdependent until they can no longer be practiced separately. Initially, marine scientists were able to focus solely on the scientific aspects of their work, interfacing with non-scientists only when seeking funding. This isolation is no longer the case as outside influences have forced scientists to interact with policy makers, international agencies and the general public.

In the 1970s, science, including oceanography and marine science, experienced an internationalization whereby U.S. scientists found that they were expected to share their knowledge and experience with scientists from other nations. Scientists were then required to work through their respective governments so that diplomatic protocols could be observed. Mechanisms of communication and interaction between scientists and their governments were established to ensure effective collaborations.

In recent years the political framework surrounding science has undergone a new development. It has become democratized. The public has begun to demand a voice in the value-laden decisions that can arise through execution of science. If marine scientists are to effectively operate within this new framework, they must understand the aspects of their work that have changed and what they can do to utilize the input of the public while minimizing the potential for negative consequences. More formal mechanisms of communication and interaction between scientists and the public are now needed to ensure effective collaborations between these two groups.

The objective of this thesis is to develop policy protocols to assist marine scientists in incorporating public input throughout their research without compromising the integrity of the science in this new era of intense public scrutiny. The emphasis is on experimentation in the oceans, which involves a modification of the ocean environment in some manner, as this particular form of research is much more likely to encounter a more stringent public scrutiny. The intense scrutiny is a result of a perception of increased risks to the public and the marine environment due to the uncertainties inherent in altering the natural ocean environment.

Because the final product of this thesis is a new set of policy protocols for marine scientists to consider when facing potential public involvement, a solid foundation for these protocols is initially established. In developing this foundation, the thesis is divided into three sections. In the first section the history of the symbiotic development of marine science and policy is explored through an analysis of national and international marine and environmental legislation to demonstrate the dependency of one upon the other and the evolving nature of their relationship. The legislation is examined to demonstrate how the responsibilities of researchers have changed over the past fifty years as knowledge of the ocean system continues to improve and as the national and international political climates evolve in consideration of this increased understanding. The second section contains several case studies of oceanographic research that demonstrate the inevitable outcome of the entwined relationship of the science and the policy discussed in the first section. The case studies provide concrete examples of research that has been practiced within the evolving political framework. A new set of policy protocols is then developed in the third section from the description and analysis of the oceanographic research case studies. These protocols are intended to guide marine scientists throughout their research so that they are able to withstand an intense public scrutiny while ensuring that their science is carried out appropriately.

1.1 The coupling of marine science and policy

The evolution of marine science and policy is explored in Chapter 2 through an analysis of national and international marine and environmental legislation. The history of such legislation demonstrates the paradigm shifts in environmental issues which have dictated the changing objectives of policy makers. As more information is obtained on the dynamics of the ocean environment, legislation that reflects this increase in understanding is introduced. As a result, the science and the policy become more intertwined.

Included in this analysis is a description of national and international legislation that may be relevant to scientists planning an experiment in the marine environment. While there are few laws that specifically address the acceptable conduct for marine researchers, there are many that restrict activities which modify the natural environment. Much of the relevant legislation involves controls on pollution and/or contamination. Other significant legislation addresses the issue of potential harm to marine mammals as well as to other forms of marine life. While many of these laws may not have originally been designed to prevent scientific research, some experiments may be considered illegal under the provisions of the legislation. Some legislation, however, takes this into account and allows permits for scientific research under certain circumstances. Whatever the case, it is in the best interests of marine scientists to be aware of the relevant legislation and the subsequent restrictions on their research.

Because the legislation that is passed is not produced in a vacuum, a description of the events surrounding the introduction and eventual acceptance of the legislation is also discussed in Chapter 2. The state of the science that exists when the policies are developed is discussed as well as the societal background within which the science is practiced. Although a better understanding of the oceans is slowly being developed, uncertainties prevail. It is the perception of these uncertainties in the context of society's needs that drives marine policy legislation.

1.2 Case studies

The effects of the interdependent development of oceanography and marine policy are then examined in Chapters 3-5 through case studies of several experiments in the ocean environment. The case studies describe experiments in three areas of research: deep-sea drilling, acoustic tomography, and CO_2 sequestration. These three fields were chosen because individually they contain representative examples of experimental ocean research conducted over the past fifty years that illustrate the various phases in the development of marine science and policy. Together they demonstrate the evolution of oceanography, from its relative autonomy in the 1950s, to its internationalization in the 1970s, to its democratization in the 1990s.

1.2.1 Deep-sea drilling

Deep-sea drilling is a method used by geologists and geophysicists to collect information about the dynamic processes of the earth. It promotes basic research into the history of the ocean basins and the nature of the earth's crust by collecting deep sediment cores from a dynamically-positioned research vessel thousands of meters above the ocean floor.[1]

The deep-sea drilling research discussed in Chapter 3 covers more than forty years of drilling programs and is therefore an excellent example of research that has a long history in the evolving marine science and policy framework. The history of deep-sea drilling reveals the relative autonomy of the scientists in the 1950s and 1960s in addition to the internationalization of the research in the 1970s. Furthermore, current events suggest that this well-established program is participating in the trend toward more democratic science by actively seeking means to increase public awareness of its affairs.[2]

The first drilling project discussed is the failed Project Mohole, which was introduced in 1957. The goal of the revolutionary Project Mohole was to drill to the

[1] JOI, "ODP's Greatest Hits: Contributions from U.S. Scientists," July 1997.

[2] ODP Review Committee, "The Ocean Drilling Program Mid-term Review," Committee Report, January 1996.

Mohorovičić discontinuity, the boundary between the earth's outer crust and the upper mantle, to determine the composition of the mantle. While initial tests showed that drilling a single deep core to the necessary depth was technologically feasible, the project became mired in politics and the expenses became overwhelming. The project was finally cancelled in 1966.[3]

The geophysical community, in the meantime, had decided it would be more cost-effective to collect numerous cores that were less deep throughout the world's oceans. This led to a more successful drilling program, the Deep Sea Drilling Project (DSDP), carried out by a consortium of oceanographic research institutions from 1968 to 1983.[4] Deep-sea drilling continues to produce valuable information on the dynamics of the geophysical processes of the earth through the current Ocean Drilling Program (ODP).[5]

Although cores have been taken from ocean basins around the world, the DSDP was initially a project sponsored solely by U.S. government funding agencies. From 1974 to 1976, however, five governments formally joined with the U.S. and the project entered its International Phase of Drilling.[6] This was done not only to distribute the costs for the large-scale, expensive project, but also to minimize international pressures on marine scientific research and to satisfy the interests of other countries, eager to share in the distribution of knowledge.[7] After the DSDP ended, the current deep-sea drilling research program, the ODP, began operations. Because these projects have never faced severe public scrutiny or negative publicity, they have not been forced to become democratized. It is interesting to note, however, that the principal scientists are actively seeking public involvement as they push to continue and expand their research beyond the current 2003 ending date of the ODP.[8]

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[3]Bates, C.C., T.F. Gaskell, and R.B. Rice, Geophysics in the Affairs of Man: A Personalized History of Exploration Geophysics and its Allied Sciences of Seismology and Oceanography, Pergamon Press, Oxford, 1982, pp. 214-219.

[4]Baker, D.J., Testimony before the House Committee on Science and Technology: Subcommittee on Science, Research, and Technology. 25 February 1986.

[5]*supra*, Note 1.

[6]*supra*, Note 4.

[7]Nierenberg, W.A., "Deep Sea Drilling – Lessons Learned," Fifth International Congress on the History of Oceanography, La Jolla, CA, 9 July 1993.

[8]*supra*, Note 2.

1.2.2 Acoustic tomography

Ocean acoustic tomography is a relatively new technique that uses sound to measure average temperatures over large regions of the ocean. Changes in the time it takes sound to travel between known source and receiver locations are related to changes in the average temperature between them. Because the ocean is relatively transparent to sound waves, analysis of travel-time data through inverse methods leads to data on sound speed. From this the temperature structure between the sound source and the receiver can be inferred.[9]

While this technique has been used to monitor temperatures in small seas and over continental shelves, the acoustic tomographic experiments described in Chapter 4 are basin-scale experiments that have generated controversy over the levels of sound needed at such large scales. In 1991 a brief feasibility test was carried out by scientists near a remote island (Heard Island) in the Southern Ocean to determine whether sound produced near the island could be heard at distances of thousands of kilometers.[10] This test raised objections from several marine mammal experts as well as environmental groups, but the experiment was allowed to proceed under the condition that a marine mammal observation component be added.[11]

After a successful test, the same scientists then designed the Acoustic Thermometry of Ocean Climate (ATOC) experiment with sound sources located off the coasts of California and Hawaii to measure temperatures across the Pacific Basin. This experiment is currently in progress and is an expansion of the Heard Island test in that it will be carried out for a longer duration, includes two sound sources, and attempts to determine whether accurate measurements of temperature can be made using this technique. Because of the location of the sound sources and the uncertainties in the effects of loud, low-frequency sound on marine mammals, an overwhelmingly negative

[9]Pickard, G.L., and W.J. Emery, Descriptive Physical Oceanography: An Introduction, 5th (SI) ed., Permagon Press, Oxford, 1990, p. 123.

[10]Munk, W. and A. Baggeroer. "The Heard Island papers: A contribution to global acoustics," J. Acoust. Soc. Am., 96(4), 1994, pp. 2327-2329.

[11]Cohen, J., "Was underwater 'shot' harmful to the whales?" *Science*, 252, 17 May 1991, pp. 912-914.

public response was generated. The fact that the scientists were completely unprepared for the public's response only served to exacerbate the situation. In the end, the design of the experiment was completely revised and the original scientists no longer have control over the sound transmission schedule in their own research program. A Marine Mammal Research Program has been added which actually determines the schedule of transmissions in addition to making the decisions regarding operations, suspension, and termination of the sound source.[12]

Acoustic tomography was chosen as the second area of research to explore because it includes the benchmark example of the democratization of oceanography. ATOC was the first oceanographic experiment to come under the intense public scrutiny that is occurring more and more frequently in science and, unfortunately, these scientists were not prepared. This case study is used as an example of the potential for negative consequences if scientists are not aware of the increased scrutiny to which their work is exposed.

1.2.3 CO_2 sequestration

The ocean storage of captured CO_2 at depth is considered to be an acceleration of the natural transfer of atmospheric CO_2 into the deep ocean, and therefore a possible mechanism for greenhouse gas mitigation. The eventual fate of the injected CO_2, however, is unknown, and researchers from around the world are working to develop a better understanding of the complex chemical, biological, and oceanographic factors that is needed before large-scale sequestration of CO_2 can be undertaken.[13]

Plans are currently underway for an experiment off the coast of Hawaii involving the injection of CO_2 into the ocean at a depth of 700-1000 m.[14] The results from this experiment will be combined with ocean circulation models and other tracer

[12]Kineon, F.P. "Acoustic Thermometry of Ocean Climate: A case study in the effect of political pressures on science," Master's thesis, U. of Washington, 15 March 1996.

[13]"Ocean Storage of CO_2: Workshop 2 - Ocean Circulation", IEA Greenhouse Gas R&D Programme, Cheltenham, UK, January 1996, p. 3.

[14]Adams, E.E., Senior Research Engineer, Department of Civil and Environmental Engineering, MIT, Cambridge, MA, Personal communication, May 1998.

experiments to help reduce the uncertainties related to the concept of deep ocean storage of CO_2. Because the injection of CO_2 into the deep ocean involves high levels of uncertainty and will be carried out in coastal waters, the experiment has a strong possibility of generating emotionally charged controversy. In addition, the fact that the international environmental community is stressing a reduction of CO_2 emissions instead of finding mechanisms to mitigate the increasing amount of emissions[15] will inevitably complicate matters further.

The CO_2 sequestration project is currently in the planning stages and does not have the amount of data the previous case studies have. Instead, this experiment is being examined in Chapter 5 because the principal scientists are working to establish an effective public outreach component to their research so that public participation may be conducted in a constructive manner. It has been chosen as a case study because it represents the change in awareness of some scientists toward the possibility of public involvement in their research. In addition, because the CO_2 sequestration experiment is still in the planning stages, it is a candidate for the application of the policy protocols developed in this thesis.

1.3 Policy protocol development

Chapter 6 is the logical outcome of the previous chapters. In examining the evolution of oceanography and examples of past and current research, it becomes apparent that the current political climate is different from any faced by marine scientists in the past. The recent development of public participation and influence in environmental issues has led to the necessity of scientists being prepared to effectively interact with the public, something they are not trained to do.

In analyzing each of the above case studies, the particulars that have allowed the scientists to successfully maintain appropriate control over their experiments will become better defined. The protocols developed in the final chapter will be based on those mechanisms that were used successfully or could have been used to improve the

[15] 1992 United Nations Framework Convention on Climate Change.

chances of success in the each of the experiments.

The policy protocols developed here cover all phases of potential research projects, from the planning and implementation stages through to the monitoring and distribution of results. They will help to guide the scientists in establishing and maintaining the public trust that is essential in any public process. A successful project will invite public scrutiny and incorporate public participation throughout the entire research project while still maintaining appropriate scientific methods and standards. Through the utilization of the new set of policy protocols, scientists should be able to incorporate public input while maintaining the integrity of their research.

Chapter 2

The Evolution of Marine Policy and Legislation

This chapter examines the evolving influence of marine policy and legislation on marine scientific research. The development of U.S. and international environmental protection legislation and the context under which it was drafted is initially discussed with an emphasis on the marine environment. An analysis of this development reveals the increasing value placed on the environment, and the ocean in particular, by the public and policy-makers. The changing paradigms under which policy-makers have operated have determined the objectives of marine legislation. The gradual transition from the concept of tradional freedom and sovereignty as the basis of the law of the sea to that of the heritage of humankind in concert with a better understanding of the limits on the assimilative capacity of the oceans has led to the development of an extensive body of legislation designed to protect the marine environment.

This general discussion is followed by a synopsis of the specific legislation that has the potential to affect marine scientific research. There is relatively little legislation that deals explicitly with marine scientific research and the responsibilities of the scientists. Most of the laws discussed below, therefore, are those that establish limits on the use of the ocean. In addition to general environmental protection legislation, other relevant legislation includes controls on pollution and/or contamination in the marine environment or addresses the issue of potential harm to marine organisms.

Although most of this legislation was not originally intended to restrict scientific research, specific experiments may fall under their jurisdiction due to the nature of the research.[16] Some legislation, however, takes this unintentional consequence into account and allows exceptions for scientific research under certain circumstances. If scientists responsible for planning and implementing ocean research and experimentation are unaware of such legal and political implications, they risk complications and delays that could jeopardize the success of their projects.

In the early stages of the development of environmental law, and the law of marine pollution in particular, it was recognized that action should be taken on three levels: global, regional and national.[17] The regional level of legislation is beyond the scope of this study, so the focus will be on the development of U.S. and global marine environmental legislation. These two categories will be further broken down into regulations governing general environmental legislation, marine scientific research, controls on pollution/contamination, and species protection where appropriate. In addition to these regulatory categories, a final section covering the recent development of legislation promoting public participation is also included as such puclic participation will also be shown to have the potential to directly affect marine scientific research.

2.1 The evolution of U.S. marine environmental legislation

Before the 1940s, most U.S. marine-related legislation dealt with navigation, transportation, and fisheries issues. Marine pollution laws were passed (1899 Rivers and Harbors Act), but the intent was primarily to keep navigable waters clear from obstacles to protect commerce. Scientists were relatively free to conduct research wherever and on whatever they wanted. It was not until the middle of the twentieth cen-

[16]It should be noted that a specific segment of legislation has been intentionally left out of this discussion. The substantial number of laws regulating oil pollution have not been included, but should be considered if the intentional dumping of oil is a component of a marine experiment.

[17]Timagenis, G.J., International Control of Marine Pollution, Oceana Publications, Inc., Dobbs Ferry, NY, 1980, pp. 39-40.

tury that the inherent value of the oceans themselves began to be recognized among policy-makers as well as the public.

In the late 1960s and early 1970s, several events and the conditions of major bodies of water combined to bring the health of the environment, specifically the nation's waters, to the forefront of the public's attentions. In 1969 the Cuyahoga River in Ohio burst into flames and a major oil spill occurred off the coast of Santa Barbara, California. Boston Harbor and the Potomac River had both become cesspools and Lake Erie was declared dead. In response to these and other situations, Congress passed several significant statutes in the 1970s to establish a broad national framework for protecting the environment.

2.1.1 General environmental legislation

Two major federal agencies were created in 1970 to promulgate regulations that would ensure a consistent approach to environmental standards. In July of 1970, the White House and Congress worked together to establish the U.S. Environmental Protection Agency (EPA) in response to the growing public demand for cleaner water, air, and land. The National Oceanic and Atmospheric Administration (NOAA) was also established in 1970 by President Nixon's Reorganization Plan No. 4 of July 9, 1970 (84 Stat. 2090) in which many science agencies with related missions were brought together in one agency.

In addition to creating federal agencies, Congress passed several statutes that promoted environmental protection. The National Environmental Policy Act (NEPA) was one of the first national level environmental protection laws ever written. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment.[18] NEPA is the basic U.S. charter for the protection of the environment. The very premise of NEPA's policy goals is to avoid, minimize, or compensate for adverse environmental impacts before an action is taken.

[18] 42 U.S.C. §4332(C).

2.1.2 Marine pollution/contamination

Other laws were specifically written to ensure the quality of the nation's waters and may restrict the types or amounts of foreign substances that scientists are allowed to inject into the water. As seen in the summary of the pollution regulations found below, most pollution prevention laws do establish a permitting process that specifies what intentional pollution may be carried out. It is within the framework of these general permits that marine scientists must be able to fit their research as exceptions are not made in favor of scientific research as they are with other permitting processes.

The Federal Government had initially promoted environmental pollution controls at the state level. The 1948 Federal Water Pollution Control Act offered state and local governments technical assistance and funds to promote efforts to protect water quality. The 1965 Water Quality Act charged states with setting water quality standards for interstate navigable waters. This fragmented approach at environmental protection slowly changed as a better understanding of the unbounded nature of aquatic systems developed and as the environment was beginning to be viewed as one complex system as opposed to many unconnected units.

The intent of the 1972 Amendments to the Federal Water Pollution Prevention and Control Act was to restore and maintain the integrity of the nation's waters and the Amendments did so by authorizing water quality and pollution research, providing grants for sewage treatment facilities, setting pollution discharge and water quality standards, addressing oil and hazardous substances liability, and establishing permit programs for water quality, point source pollutant discharges, ocean pollution discharges, and dredging or filling of wetlands.[19] This landmark legislation not only strengthened the existing water quality standards, but also established a framework of standards, technical tools and financial assistance to counter the many causes of water pollution. It is the primary federal law that protects the health of the U.S. aquatic environments and is enforced by the EPA. Individual states are authorized under the Act to establish their own standards, as long as such standards are at least

[19] 33 U.S.C. §1251-1387.

as stringent as those mandated by the EPA.

The U.S. had also become concerned about the disposal of wastes at sea by this time as well. The first major systematic study of the problems posed by dumping at sea was issued by the U.S. Council of Environmental Quality in October 1970. The conclusion of the report was that although ocean dumping was not a major source of pollution at that time, there was a need for urgent action at both the national and international levels to prevent the problem from growing to a great magnitude.[20] As a result, the Ocean Dumping Act was passed in 1972. It prevented unacceptable dumping in the oceans.

As more information became available on the chemical and physical properties of the ocean environment, the legislation of the early 1970s was amended to strengthen the existing regulations and to include newly discovered contaminants. The 1977 Clean Water Act Amendments, for example, strengthened controls on toxic pollutants.

2.1.3 Species protection

In addition to the trend toward regulating the introduction by man of substances into the marine environment that may cause deleterious effects, the 1970s also witnessed the creation of legislation protecting marine organisms for the first time.[21] Like the marine pollution legislation, these regulations will prevent marine scientists from disturbing the marine environment unchecked, but do provide exemptions. In fact, this particular type of legislation accounted for the necessity of scientific research to harm marine organisms on occasion and established specific permit processes especially for scientific research.

Prior to the passage of the Marine Mammal Protection Act (MMPA) of 1972, individual states were responsible for the marine mammals on the land and in the waters under their jurisdiction. The MMPA vested marine mammal management authority

[20] *supra*, Note 17, pp. 171-172.

[21] The extensive legislation on the management of fisheries and fish stock is not included in this discussion as this type of marine life was recognized as a valuable economic resource as early as 1871 when Congress established the U.S. Commission of Fish and Fisheries.

in the Federal Government. In striving to maintain marine mammal populations at sustainable levels, the MMPA established a moratorium, with certain exceptions, on the taking of marine mammals in U.S. waters or on the high seas by U.S. citizens.[22] It also banned the importation of marine mammals or their products into the United States.[23] The Endangered Species Act (ESA) was enacted in 1973 to mitigate the impact of human activity on species in danger of extinction. Affected species are either considered endangered, those species in danger of becoming extinct.[24] Both of these Acts have the potential to limit marine research, especially when uncertainties over the degree of potential harm are prevalent.

2.1.4 Public participation in environmental protection

After having established a national legislative framework, the Federal Government has begun to allow states to assume responsibility for federal programs while still retaining oversight authority. In addition to broadening the responsibility of environmental protection to a regional scale, an emphasis has recently been put on incorporating public participation.

An example of such a restructuring is within the EPA. The current EPA mission statement includes providing the best customer service possible. The approach to this goal is based on three principles: 1) encouraging public participation, 2) providing access to information, and 3) responding to the customer's needs.[25] In order to accomplish its mission, the EPA is working in partnerships with states, local communities, tribal governments, industry and environmentalists to implement the many environmental protection laws that Congress has passed. The new generation of environmental protection is considered to be community-based and is a goal-driven, rather than program-driven, approach to restoring and sustaining healthy human and ecological communities.[26]

[22] 16 U.S.C. §1371(a).
[23] *Ibid.*
[24] 16 U.S.C. §1531(b).
[25] USEPA, "Putting Customers First: EPA's Customer Service Plan," EPA 230-B-95-004, September 1995.
[26] USEPA, "Employment Information," EPA Office of Human Resources and Organi-

Marine scientific research must now be considered within this new public-participation framework. The effects of this expansion of responsibilities is not yet clear and the roles of the scientists and the public are still developing.

2.2 The evolution of global marine environmental legislation

The international community closely followed the developments of the United States and much of the current environmental legislation is drafted at an international level. As a result, many of the principles of international environmental law serve either as guidelines for national level policy or as substitutes for national policy when their equivalents do not exist. The global rules promote a universal uniformity of norms whereas national legislation is used for the purpose of supplementing and giving effect to international rules.[27]

2.2.1 General environmental legislation

Because of the tendency to address very specific problems in international legislation, there are no relevant conventions that govern the general health of the environment. There are, however, several relevant principles of international environmental law that are at the foundation of much of the international environmental policy. These principles are reflected in the Rio Declaration on Environment and Development:

- Precautionary Principle - Where there are threats of serious or irreversible damage, the lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

- Principle of Good Neighbourliness - States should effectively cooperate to discourage or prevent the relocation and transfer to other States of any activities

zational Services: Office of Administration and Resources Management, (available at http://www.epa.gov/epahrist/, April 1998).

[27] *supra*, Note 17, p. 41.

and substances that cause severe environmental degradation or are found to be harmful to human health.

- Principle of Good Governance, including Participatory Democracy - Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.

- Principle of Sovereignty over Natural Resources and the Responsibility not to cause Environmental Damage - Nations have the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[28]

These principles are the product of the general trend over the years toward a more protective approach to the environment. They are the skeleton upon which most national legislation is based and must be kept in mind by marine researchers as the principles define the current attitude toward the responsibilities of nations, and therefore of individuals, to the environment.

2.2.2 Marine scientific research

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) is the one piece of legislation that specifically outlines rules for marine scientific research and

[28] "Rio Declaration on Environment and Development," The United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 3-14 June 1992.

the responsibilities of both the coastal states as well as the researchers. In general, this Convention represents the codification of customary law. In addition, it sets the standard for potential uses of the world's oceans and affects the drafting of national legislation even in countries where it has not been ratified.

Marine scientific research discussions prior to the finalization of the 1982 Convention focused on the potential impact the Convention would have on the scope, nature, and location of worldwide marine scientific research activities.[29] Prior to the implementation and ratification of the 1958 Convention on the Continental Shelf in 1964, coastal state restrictions on oceanographic research conducted beyond territorial sea limits were virtually unknown. After 1964, however, claims to greater coastal state control began to afffect many research activities.[30] The problem was not only an increased number of coastal state refusals. Many oceanographic projects were delayed due to lengthy time-consuming procedures often required to obtain permission and others were abandoned or indefinitely postponed as a result of such actions.[31] While the financial losses incurred by such delays and refusals were enormous, the scientific community was more distressed by the scientific losses as many of the most complex and important problems are found in coastal areas and seldom correspond to political boundaries.[32]

The 1982 UNCLOS resolved many of the uncertainties in coastal state consent procedures and established a framework for the conduct of marine scientific research. Part XIII of the Convention, Marine Scientific Research, confirms that all states and international organizations have the right to conduct marine scientific research, subject to the provisions of UNCLOS. It also creates obligations for states to cooperate in the scientific research field. It creates a relatively flexible working environment for marine scientists within the high seas and grants most of the decision making authority to the discretion of the coastal states for work in jurisdictional waters

[29]National Academy of Sciences, "Marine Scientific Research and the Third Law of the Sea Conference," U.S. National SCOR Committee report, Washington, D.C., 1974, p. 1.
[30]*supra*, Note 29, p. 2.
[31]*Ibid.*
[32]*supra*, Note 29, p. 3.

while providing guidelines for a consistent permitting process.[33] While specifically addressing the rights of researchers, marine scientific research is still set within the context of the overall goals of the Convention and is constrained by the potential it has to affect the marine environment. (The UNCLOS approach to the protection and preservation of the marine environment is discussed further in the following section.)

2.2.3 Marine pollution/contamination

The sea has been traditionally used by man as a site for the disposal of wastes.[34] According to Grotius, the oceans could be used as a dumping ground because it did not appear to interfere with other uses of the oceans.[35] This attitude has slowly changed over the past forty years.

International concern with marine pollution first took a practical form in the 1950s and resulted in multilateral international conventions specifically addressing this problem. Until the early 1970s, the concern was basically limited to oil pollution. Conventions on nuclear ships and nuclear damage treated the matter as a dangerous activity rather than an environmental isssue.[36] The 1970s, however, saw a dramatic increase in the number of conventions with principal environmental objectives that were not just limited to oil or radioactive pollution. These conventions took place during, and were influenced by, the preparation of and the negotiations in the Third UN Conference on the Law of the Sea.[37]

The UN Conference on the Human Environment took place in Stockholm in June 1972. This conference did not adopt a treaty, but did give concrete form to the existing concern for the environment and provided the motive force for further action.[38] The defintion of marine pollution developed for this conference connects the concept of

[33] 1982 UNCLOS, Articles 245-246.
[34] *supra*, Note 17, p. 109.
[35] Van Dyke, J.M.,"International Governance and Stewardship of the High Seas and Its Resources", Freedom for the Seas in the 21st Century: Governance and Environmental Harmony, Van Dyke, J.M., D. Zaelke and G. Hewison, eds., Island Press, Washington, D.C., p. 16.
[36] *supra*, Note 17, p. 4.
[37] *supra*, Note 17, p. 9.
[38] *supra*, Note 17, p. 10.

marine pollution to a human activity causing certain undesirable results to the marine environment and has become the basis for all subsequent definitions. The Conference defined marine pollution as:

> The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality or use of sea water, and reduction of amenities.[39]

Conventions on marine pollution adopted prior to 1972 do not include any definition of marine pollution since they relate to specific types of harm or danger to the environment. Legal texts adopted from 1972 to 1974 use this definition implicitly in the basic obligation for the protection of the marine environment. Legal texts prepared from 1974 onwards, however, include an express definition of the term "marine pollution."[40] The conclusion can therefore be drawn from the development of the definition of pollution, that the international law of the sea transitioned to an environmentally stronger regime throughout the 1970s.[41]

Several factors contributed to the focused attention on marine pollution during this period. Increased ocean disposal of industrial wastes, off-shore exploitation of hydrocarbons, and deep-sea mining revealed new sources of marine pollution. The rapid growth of tanker tonnage and a number of accidents with disastrous pollution results also gave the international community opportunities to appreciate the existing and approaching dangers from pollution. Economic conditions also increased the importance of marine resources at the same time developments in fishing technologies and marine pollution combined to create severe risks of deterioration or destruction to those resources.[42]

Pursuant to the Stockholm conference, an international conference was convened from October 30 to November 13, 1972 and adopted the Convention on the Prevention

[39] *supra*, Note 17, p. 23.
[40] *supra*, Note 17, pp. 23-24.
[41] *supra*, Note 17, p. 25.
[42] *supra*, Note 17, pp. 33-34.

of Marine Pollution by Dumping of Wastes and other Matter (London Convention on Dumping), the first convention to address ocean dumping at a global scale.[43]

One of the most influential international conventions on environmental protection in the ocean, the 1982 UNCLOS, was then based on the preceeding work. Discussions leading to the framing of this Convention in the 1970s made it clear that the global community recognized the need for international standards to be established with respect to the multiple uses of the ocean and its resources.

2.3 Legislation affecting marine scientific research

What follows is a description of national and international legislation that may be relevant to marine scientific research.[44] Because the emphasis is on experimentation in the marine environment, the legislation described below was chosen for its potential impact on this type of marine scientific research. While there are few laws that specifically address the acceptable conduct for marine researchers, there are many that restrict activities which modify the natural environment. In addition to general environmental protection legislation, other relevant legislation involves controls on pollution and/or contamination in the marine environment and marine species protection. While the following is not an exhaustive list of the potentially relevant legislation, it effectively summarizes the current policy of the U.S. and the international community toward the use of the oceans.[45]

2.3.1 General environmental legislation

While most of the legislation that may apply to experimentation in the oceans specifically addresses marine environmental concerns, there is important general national environmental legislation to consider as well.

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[43] *supra*, Note 17, p. 11.

[44] A chronological list of the legislation may be found in Appendix A.

[45] When operating in coastal waters, scientists must be aware of local regulations as states and other nations may have enacted standards that are more stringent than the internationally recognized limits.

National Environmental Policy Act of 1969, 42 U.S.C. §4321-4370

Because of its comprehensive coverage over environmental issues and its strict requirements, NEPA is of primary importance. NEPA was passed by Congress to ensure that any government sponsored project or action take into account and assess the potential environmental impact of the project. NEPA requires that "all agencies of the Federal Government shall . . . include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on –

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."[46]

Thus, NEPA requires an extensive Environmental Impact Statement (EIS) from researchers proposing to significantly modify the natural environment. The environmental impact assessments are then evaluated for their conformity to the objectives of appropriate agency regulations propagated under such legislation as the Marine, Protection, Research and Sanctuaries Act or the Clean Water Act.

Of relevance to this discussion are two other NEPA requirements that address the possibility of controversial propositions. First, NEPA requires agencies to use a systematic, interdisciplinary approach to all planning and decision-making so that the uncertainty inherent in environmental assessments is mitigated and all environmental

[46] 42 U.S.C. §4332(C).

resources may be given appropriate consideration.[47] In addition, NEPA specifies requirements for publishing the proposed action in the Federal Register so that the public may comment and request special hearings.[48] All such public comments must then be responded to in the EIS as required by NEPA.

2.3.2 Regulations addressing marine scientific research

While much of the national level environmental legislation includes provisions to promote research in general, few laws actually provide any guidance as to what constitutes appropriate marine scientific research. The Marine Protection, Research, and Sanctuaries Act of 1972 is an exception.

At the international level, the key legislation is the 1982 United Nations Convention on the Law of the Sea. This major Convention is unique in that it specifically addresses marine scientific research and provides guidelines for the conduct of research, especially within the international community.

Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. §1441-1445

Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA) authorizes the designation of discrete areas of the marine environment as National Marine Sanctuaries to protect distinctive natural and cultural resources whose protection and beneficial use requires comprehensive planning and management. The Act also established the National Marine Sanctuary Program (NMSP), which is administered by the Sanctuaries and Reserves Division of NOAA.[49]

The mission of the NMSP is to identify, designate and manage areas of the marine environment of special national significance due to their conservation, recreational, ecological, historical, research, educational, or aesthetic qualities. The goals of the

[47] 42 U.S.C. §4332(A).
[48] 42 U.S.C. §4332(C), 5 U.S.C. §552.
[49] NOAA,"National Marine Sanctuary Program Mission," Office of Ocean and Coastal Resource Management, NMSP, (available at http://wave.nos.noaa.gov/ocrm/nmsp/welcome.html, May 1998).

NMSP are to provide enhanced resource protection through conservation and management of the Sanctuaries that complements existing regulatory authorities; to support, promote, and coordinate scientific research on, and monitoring of, the site-specific marine resources of the Sanctuaries; to enhance public awareness, understanding, appreciation, and wise use of the marine environment; and to facilitate, to the extent compatible with the primary objective of resource protection, multiple uses of the National Marine Sanctuaries.[50]

Like similar environmental legislation, Title III of the MPRSA promotes scientific research. Because of the specific objectives of the MPRSA, however, there are very precise limits on the types of research that may be conducted within the jurisdiction of the MPRSA. Since the general mission of the MPRSA is to promote the preservation of the National Marine Sanctuaries, it is unlikely that experiments that may significantly modify the natural environment will be permitted to be conducted within a sanctuary.

1982 United Nations Convention on the Law of the Sea - Part XIII

The 1982 UNCLOS specifically outlines rules for marine scientific research. In addition to very specific provisions as to the responsibilities of the coastal states as well as the scientists, UNCLOS also provides general principles for the conduct of marine scientific research:

(a) marine scientific research shall be conducted exclusively for peaceful purposes;

(b) marine scientific research shall be conducted with appropriate scientific methods and means compatible with this Convention;

(c) marine scientific research shall not unjustifiably interfere with other legitimate uses of the sea compatible with this Convention and shall be duly respected in the course of such uses;

[50] *Ibid.*

(d) marine scientific research shall be conducted in compliance with all relevant regulations adopted in conformity with this Convention including those for the protection and preservation of the marine environment.[51]

Once again, research is constrained by the potential it has to affect the marine environment. (The UNCLOS provisions on the protection and preservation of the marine environment are discussed in the following section.)

2.3.3 Marine pollution/contamination legislation

The regulatory structure of the U.S. concerning ocean dumping is similar to that of the international structure. Most highly toxic materials are prohibited from being dumped and all other materials are subject to the process of permit applications reviewed by the appropriate regional administrator of the EPA.[52]

1972 Amendments to the Federal Water Pollution Prevention and Control Act, 33 U.S.C. §1251-1387

The Federal Water Pollution Prevention and Control Act specifically protects wetlands and other aquatic habitats through a permitting process that ensures activities are conducted in an environmentally sound manner. It is unlawful for any person to discharge any pollutant from a point source into navigable waters under the Act unless a permit is obtained. The permits specify:

- the amount and concentration of pollutants the holder is authorized to discharge,
- schedules directing when compliance must be achieved,
- the requirements for testing, and monthly or quarterly reporting to the permitting authority.[53]

[51] 1982 UNCLOS, Article 240.

[52] Auerbach, D.I., J.T. Kildow, H.J. Herzog, and E.E. Adams, "Legal and Political Aspects of CO_2 Ocean Disposal," Environmental Impacts of Ocean Disposal of CO_2: Volume 2 - Topical Reports, MIT Energy Laboratory Report 96-003, December 1996.

[53] 33 U.S.C. §1342.

Permits may therefore be obtained for marine scientific research, but are not guaranteed. Exceptions are not explicitly made for scientific research, so scientists receive no special consideration under this Act.

Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. §1441-1445

Not only does the MPRSA cover sanctuaries, Title II of the MPRSA (the Ocean Dumping Act) prohibits unacceptable dumping in the ocean. Congress declared that "it is the policy of the United States to regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[54].

Permits are also granted under the Ocean Dumping Act and are similar in their to those of the Federal Water Pollution Prevention and Control Act permits in that they specify when and what dumping may occur.[55] Permits are granted only after the EPA "gives notice and opportunity for public hearings" and "determines that such dumping will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[56] Consideration may be given to the need for the proposed dumping,[57] but there is no specific category for marine scientific research.

1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter

This Convention, commonly known as the London Dumping Convention (LDC), is the most restrictive regulation framework governing dumping from ships. The definition of ocean dumping is "i) any deliberate disposal at sea of wastes or other mater from vessels, aircraft, platforms or other man-made structures at sea. ii) any deliberate

[54] 33 U.S.C. §1401(b).
[55] 33 U.S.C. 1414(a).
[56] 33 U.S.C. §1412(a).
[57] 33 U.S.C. §1412(a)(A).

disposal at sea of vessels, aircraft, platforms or other man-made structures at sea."[58]

The Convention separates potential pollutants based on the danger to the environment presented by the materials into three classes called annexes. Annex I materials are considered to be extremely dangerous substances (organohalogen compounds, mercury, cadmium, oil, plastics, high-level radioactive wastes, and materials of chemical warfare) and are completely prohibited from being dumped at sea except in trace amounts that would be "rapidly rendered harmless by physical, chemical or biological process in the sea."[59]

Dumping of materials in Annex II (wastes containing significant amounts of arsenic, lead, copper, zinc cyanides, fluorides, beryllium, chromium, nickel, vanadium, other radioactive wastes not included in Annex I, and large quantities of acids or alkalis containing any of the above metals) require a special permit issued by the State. Annex III includes all other matter or wastes, which require a general permit in order to dump.[60] The Annexes are continuously updated to reflect changes in the understanding of the ocean environment as well as the introduction of new chemical species to the international community. This Convention will obviously affect scientific research that involves the injection of substances covered under the annexes from ship-based sources, if only by requiring permits to be obtained.

1982 United Nations Convention on the Law of the Sea - Part XII

The most advanced definition of marine pollution in the course of the development of the concept is the one put forward by UNCLOS. It defines marine pollution to be:

> The introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use

[58] 1982 LDC, Article 3.
[59] LDC, Article 4 and Annex I.
[60] LDC, Article 4.

of sea water and reduction of amenities.[61]

This definition is an expansion on the basic elements of the original one formulated for the UN Conference on the Human Environment discussed above.

Part XII of the Convention, Protection and Preservation of the Marine Environment, submits that "State have the obligation to protect and preserve the marine environment."[62] It goes on to establish measures to prevent, reduce and control pollution of the marine environment.[63] The reference to the necessity to protect the marine environment in Part XIII of the Convention makes it clear that marine science research does not outweigh the provisions established here and that any experiment that proposes to inject alien substances into the ocean that have the potential to cause harm will be subject to this Act.

2.3.4 Species protection legislation

Any experimentation that may affect marine biota may come under two very stringent U.S. species protection laws, the Marine Mammal Protection Act and the Endangered Species Act. The relevant objective of these laws is the protection of marine species from man's activities.[64] Both offer waivers for scientific research, but the permitting process can be very political.

Marine Mammal Protection Act of 1972, 16 U.S.C. §1361-1421

In striving to maintain marine mammal populations at sustainable levels, the MMPA established a moratorium, with certain exceptions, on the taking of marine mammals in U.S. waters or on the high seas by U.S. citizens.[65] It also banned the importation of marine mammals or their products into the United States.[66] The term "take" is defined to mean "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture,

[61] 1992 UNCLOS, Article 1(1)(4).
[62] 1982 UNCLOS, Article 192.
[63] 1982 UNCLOS, Article 194.
[64] Note that the ESA also provides protection for land based species.
[65] 16 U.S.C. §1371(a).
[66] *Ibid.*

or kill any marine mammal."[67] Because of the broad definition used, many research projects may unintentionally warrant additional scrutiny under the MMPA. Although permits may be issued for public display and scientific research,[68] the permits are very specific in the numbers and species of animal that can be taken, as well as times, dates, places, and methods of taking.[69] In addition, before a permit is granted for the proposed taking or importation, the proposal is first reviewed by the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals.[70]

Under the MMPA Amendments of 1994, a definition of harassment was added to the Act differentiating between Level A, which has the potential to injure a marine mammal or stock, and Level B, which has the potential to disturb but not injure a marine mammal or stock. The permit requirement may now be waived provided that the proposed activity results in only harassment, and no serious injury or mortality is anticipated. The Amendments also require the National Marine Fisheries Service (NMFS) in the Department of Commerce and the U.S. Fish and Wildlife Service (FWS) in the Department of the Interior to promulgate regulations authorizing bona fide scientific research involving only Level B harassment without a formal permit. To get the permit requirement waived, specified information must be submitted to NMFS or FWS at least 60 days prior to beginning research. Also, expedited scientific research permits will now be allowed when delay could cause injury to a marine mammal or loss of unique research opportunities.[71]

Prior to the passage of the MMPA, individual states were responsible for the marine mammals on the land and in the waters under their jurisdiction. The MMPA vested marine mammal management authority in the Federal Government. States can regain their authority on a species-by-species basis if their conservation and management programs are found to be consistent with the purposes and policies of the Act.[72]

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[67] 16 U.S.C. §1362(13).

[68] 16 U.S.C. §1371(a)(1).

[69] 16 U.S.C. §1374(b)(2).

[70] 16 U.S.C. §1371(a)(1).

[71] Buck, E.H., "Marine Mammal Protection Act Amendments of 1994," CRS Report for Congress, 94-751 ENR, 28 September 1994.

[72] 16 U.S.C. §1379.

Care must be taken, therefore, to ensure that state regulations are also complied with when permits for research that may affect localized biota are being considered.

Endangered Species Act of 1973, 16 U.S.C. §1531-1544

The ESA was enacted to mitigate the impact of human activity on species in danger of extinction. Affected species are either considered endangered, those species in danger of becoming extinct throughout all or a significant portion of their range, or threatened, those species likely to become endangered within the near future. Anyone may petition to have a species considered for listing as endangered or threatened, and once approved for the list, a species and its habitat become protected under the ESA. The FWS is responsible for terrestrial and freshwater species. The NMFS is responsible for marine species and Pacific salmon.

As under the MMPA, proposed research projects that could potentially affect species covered under this Act are subject to a detailed review. Projects which include destruction of areas designated as critical habitats are also subject to this review. Federal action agencies are prohibited from taking any action which might threaten a listed species under the ESA unless a special waiver has been issued. Non-federal activities which may affect listed species are also covered under the Act and may also be issued permits by the NMFS for incidental take when it occurs under scientific purposes. Applications for waivers must include a conservation plan that specifies:

(i) the impact which will likely result from such taking;

(ii) what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps;

(iii) what alternative actions to such taking the applicant considered and the reasons why such alternatives are not being utilized; and

(iv) such other measures that the Secretary may require as being necessary or appropriate for purposes of the plan.[73]

Again the agency must provide an opportunity for public comment[74] before granting any waivers.

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[73] 35 U.S.C. §1539(2)(A).
[74] 35 U.S.C. §1539(2)(B).

Chapter 3

Deep-Sea Drilling

The evolution of oceanography and marine policy will now be examined through several case studies of oceanographic research. These examples of marine scientific research describe experimentation in the ocean because they actually modify the ocean environment to some degree and do not just take measurements of oceanographic properties. As will be seen, this subtle difference will have a substantial influence on the external public pressures on the research. The case studies have been chosen as examples of experimental oceanographic research that demonstrate the transitions of internationalization and democratization in the evolution and marriage of marine science and policy processes during the last half of this century. Each experiment illustrates unique aspects of the commingling of marine science and policy.

The first example, deep-sea drilling, has a long history in the evolving marine science and policy framework. After a rocky start to drilling research, the Deep Sea Drilling Project (DSDP) was introduced in 1966 as a comprehensive drilling program designed to extract hundreds of sediment cores from the ocean floor in an effort to learn more about the structure and composition of the earth's crust.[75] The research was extremely successful and continues today under the Ocean Drilling Program (ODP), providing more information on the history of the earth through the deep-sea sediments obtained in coring.[76] While the goal of deep-sea drilling is to obtain samples

[75] *supra*, Note 3, pp. 156-158, pp. 214-219.
[76] *supra*, Note 1.

of sediment and is not obviously an experiment, it qualifies for the definition of experimental research used in this thesis. The sampling method significantly modifies the benthic environment at the drill site and has the potential to seriously pollute the overlying water column should the drill reach an undetected hydrocarbon deposit and cause an underwater blowout.

Deep-sea drilling is an excellent candidate for analysis because it covers the entire time period of interest and has successfully endured the changing political and sociological climates. The scientists involved in this research have adeptly transitioned from an independent phase into an international phase and are now attempting to promote public awareness to enter a more democratic phase. Deep-sea drilling will be described in the context of these three phases to emphasize the transitions and the roles of the scientists in these transitions.

The DSDP began in the 1960s when funding was relatively abundant and competition for those funds was almost nonexistent. Scientists were able to conduct their research without much external involvement.[77] With the 1970s came international pressure to distribute scientific knowledge and experience to the international community about global resources as well as domestic pressure to reduce and distribute the growing costs of large-scale research. In response to these and other pressures, the DSDP became an international project in 1974[78] and the DSDP soon became an ideal example of a successful international scientific collaboration.[79] Deep-sea drillng research continues to exist through the ODP and current plans are to extend deep-sea drilling research past its current ending date in 2003 by expanding current operations and developing a new set of research goals. In furthering this expansion, the ODP project managers are actively seeking to enter a more democratic phase in their research by inviting public involvement in an attempt to garner support for future funding.[80]

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[77]Ellins, K.K., Science Coordinator, JOIDES office, Personal communication, March 1998.

[78]*supra*, Note 7.

[79]Nierenberg, W.A., "The Deep Sea Drilling Project after Ten Years," *American Scientist*, 66(1), January-February 1978, pp. 20-29.

[80]JOI, "Understanding Our Dynamic Earth Through Ocean Drilling: Ocean Drilling Program Long Range Plan," March 1996.

What follows is a chronicle as well as an analysis of the development of deep-sea drilling over the last fifty years, from its unusual introduction up to its current state as a respected project. The history of deep-sea drilling and the changes it underwent as the science and technology evolved in the socio-political framework will initially be examined. Since this history includes the failed first effort at large-scale deep-sea drilling, Project Mohole, the first section of this chapter will be devoted to a description of Project Mohole and an analysis of why it failed. The second section will then introduce and dissect the DSDP and ODP, emphasizing the transitions in the research to internationalization and then to democratization. In preparation for the development of the policy protocols in the final chapter, the third section will then analyze the research in terms of its benefits and risks, both perceived and real. This final section will be an attempt to draw out the relevant factors that have allowed it to endure as long as it has.

3.1 Project Mohole

While the first attempt at large-scale deep-sea drilling, Project Mohole, failed to accomplish its objectives and was eventually cancelled by Congress, an analysis of the project is included here to emphasize several of the reasons that its successor, the DSDP, prevailed. Project Mohole is especially important as it sets the stage for the introduction of the DSDP.

3.1.1 Introduction of deep-sea drilling

Drs. Gordon Lill and Carl Alexis of the Office of Naval Research (ONR) whimsically formed the American Miscellaneous Society (AMSOC) in 1952 to deal with the large number of oceanographic research proposals that did not fit into any of the usual scientific categories. In 1957, at an informal gathering of prominent oceanographers, Dr. Walter Munk of the Scripps Institution of Oceanography (SIO) and RADM Harry Hess, USNR of Princeton, were lamenting the fact that they considered all of the currently proposed research unimaginative. Munk then proposed the radical idea of combining the technologies of offshore drilling and new methods of deep-sea drilling to drill into the earth's crust to determine the composition of the mantle. The plan was to drill a hole in the ocean floor until just below the Mohorovičić (Moho) Discontinuity, the interface between the earth's crust and the mantle.[81] By 1949, using seismic refraction studies, Dr. Maurice Ewing of Lamont had determined that the Moho interface was about 13 km below the seafloor while it was about 45 km underneath continental land masses.[82] The seafloor, therefore, was the logical place to drill.

Although Munk's idea was revolutionary, it was not the first time that a scientist had proposed deep-sea drilling. In 1943 Professor T. A. Jaggar, founder of the Volcano Observatory on Hawaii's Mount Kilaeua, had suggested that an ideal post-war project would be to drill a thousand holes in the world's oceans to obtain core samples to a depth of approximately 0.3 km.[83] In addition, a large number of deep-sea cores already had been studied and described as a result of the HMS *Challenger* expedition of 1872-1876. While these cores did not cover a long period of time because of their shallow penetration depths, they allowed an inventory of deep-sea sediment types to be identified.[84]

Soon after the informal meeting, Hess brought the proposal to ONR which then submitted it to the National Science Foundation (NSF). The NSF initially rejected the proposal as "crazy." Hess then turned to the National Research Council (NRC), the operating arm of the National Academy of Sciences, and convinced them to form the "AMSOC Committee on the Moho," chaired by Dr. Gordon Lill. This time NSF granted $15,000 to NRC to carry out a planning study directed by Dr. Willard F. Bascom.[85]

The first offshore hole was drilled in March, 1961 40 km west of Scripps in 943 m of water. A barge operated by the Global Marine Exploration Company was held in place by four 200-horsepower outboard motors operated from a central joystick. In

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[81] *supra*, Note 3, pp. 156-157.
[82] *supra*, Note 3, p. 157.
[83] *supra*, Note 3, p. 217.
[84] *supra*, Note 3, p. 13.
[85] *supra*, Note 3, p. 157.

April, 1961 the same barge pulled a long core of basalt from 200 m below the sea floor in a water depth of 3,537 m off Baja, California.[86]

3.1.2 The demise of Project Mohole

Although Bascom recommended a conservative approach to future drilling, the NSF had taken over direct project management from the AMSOC committee and decided to expand the project at a more rapid rate. The AMSOC committee had become merely an advisory group to Project Mohole. Bascom thought that drilling from this point forward should be done off of an intermediate size drill-ship of an existing type and that the technical progress should be made in finite increments. Instead, NSF held a public briefing on July 27, 1961 to set forth its request for proposals. They invited contractors to bid on the largest drilling ship ever built. The successful contractor would be responsible for 1) designing and building the ship, 2) locating suitable drilling sites, and 3) drilling a series of holes which would penetrate the earth's upper mantle. The NSF required that the contractor have "necessary experience, organization, technical qualifications, skills and facilities or the ability to obtain them." In addition, they were to have "interest and enthusiasm in undertaking the Mohole project." The proposals were due on September 11, 1961.[87]

Eleven contractors, including the Global Marine Exploration Company, submitted proposals. The selection process quickly became mired in politics and eventually Brown and Root, Inc. of Houston, a leading offshore engineering firm, was named as the Mohole contractor. Although many of the personnel believed that the Global Marine Exploration Company was the best firm in existence for experimentation in new deep-sea drilling techniques, they had paired up with Shell Oil. The director of NSF had avoided awarding the contract to any of the major oil companies as he felt that their interest in oil exploration over science outweighed their extensive technical expertise. Lill and Bascom dissociated themselves from the project and Lill was replaced as the AMSOC committee chair by Dr. Hollis D. Hedberg, Vice-

[86] *supra*, Note 3, pp. 157-158.
[87] *supra*, Note 3, pp. 214-217.

president of the Gulf Oil Corporation and an adjunct professor in geology at Princeton University. Hedberg, however, supported Jaggar's original suggestion and thought that the project would be better if a large number of holes to moderate depths were made instead of one large Mohole. He peddled this intermediate approach around Washington, D.C. and by November 1963 he was replaced as the chairman of the AMSOC Advisory Committee to NSF.[88]

Two months later, NSF announced the new chair – Dr. Gordon Lill. The project was to proceed as originally designed. Lill, however, immediately encountered problems. In 1959 the AMSOC committee, chaired by Lill, had originally proposed that the effort could be done for under $10 million. Upon Lill's return to the project, he found that the overall project cost was approaching $68 million. In early 1965 the Moho drill site was selected to be just south of the Hawaiian Islands, but soon after one of the project's main supporters on Capital Hill died (Congressman Albert Thomas of Houston, Texas). The new chair of the authorizing committee (Congressman Joe Evins of Tennessee) was not as supportive of the project that by now was approaching $125 million in total project costs and moved to kill the project. In August 1966, NSF announced that Project Mohole was to be discontinued.[89]

There were many reasons Project Mohole was doomed to failure. First, there were very few marine geologists actually in support of the project. Most marine scientists thought that an ocean sediment coring program would be more beneficial than one deep hole. Instead, Project Mohole was a pet project of a few scientists, many outside of the geological community.[90] In addition, although they were initially given free reign, the scientific community that was behind the project was not able to maintain control of its fate due to the involvement of the NSF, the White House, and Congress.[91] Finally, at the time the project started, offshore drilling was limited to water depths of 100 m or less and was usually accomplished from platforms that were

[88] *supra*, Note 3, pp. 217-218.
[89] *supra*, Note 3, pp. 218-219.
[90] *supra*, Note 7.
[91] *Ibid.*

anchored in place.[92] To achieve the goal of drilling in very deep water, therefore, the scientists became very involved in the research and development of drilling technology. This R&D was expensive and the project costs soon outweighed any potential benefits.[93]

3.2 The Deep Sea Drilling Program and Ocean Drilling Project

While the one deep hole to the upper mantle would not be accomplished, interest within the geophysical community in deep-sea drilling had blossomed. Several consortia had formed to advance the field of deep-sea drilling and attempted to distance themselves from the aborted Project Mohole. One of these, the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), was successful in 1966 in receiving funding from NSF for a small-scale drilling project on the Blake Plateau off eastern Florida (the Ocean Sediment Coring Project). Previous consortia had failed primarily because of the lack of cooperation between institute heads. JOIDES, however, was organized through the work of several senior scientists at the original institutions: the Scripps Institution of Oceanography, the Woods Hole Oceanographic Institution, the Lamont Geological Observatory and the University of Miami.[94] With Miami as the lead institution for the original work over the Blake Plateau, the consortium commenced drilling with one of Global Marine's dynamically positioned drill-ships that was on its way to the Grand Banks of Newfoundland under contract to an oil company. The drilling went smoothly, but it was less a test of the technology than a test of the flexibility of the four institutions to work effectively and harmoniously together.[95]

Because the contractual and scientific aspects of this project worked out well, in 1967 the NSF awarded JOIDES $12.6 million for an 18-month drilling program in

[92] *supra*, Note 3, p. 158.
[93] Nierenberg, W.A., Personal communication, April 1998.
[94] *supra*, Note 7.
[95] *Ibid.*

both the Atlantic and the Pacific Oceans.[96] Since the NSF was only able to guarantee $6 for the first year, the University of California took responsibility for covering any remaining costs if the project had to be cancelled due to a lack of funds.[97] NSF recognized Scripps Institution of Oceanography as the head of operations for JOIDES and the DSDP was established to gather scientific information that would help determine the age and processes of development in the ocean basins.[98] The DSDP had entered its first phase.

The initial 18-month contract with the NSF was for starting and operating the program. In addition, there was a three-year renewal option with a release clause every six months during that period.[99] Continued success in the collaboration between academia, industry and government led to the three-year extension of the contract from the NSF to Scripps to begin in 1969. The director of Scripps, Dr. William Nierenberg, had wanted to transfer the program to some other entity after the initial phase was over since he felt that there was no possibility that the program could be more successful and that there was always the chance of some political or operational failure. The geophysicists and geologists at Scripps, however, felt that it was their institutional responsibility to continue, particularly because of the failure of several previous efforts of institutional cooperation.[100]

A subcontract was given to Global Marine to build and operate a new drill-ship, the *D/V Glomar Challenger*. In order to avoid some of the problems that plagued Project Mohole, the chief scientists of the DSDP determined that they would avoid all internal development as much as possible and leave the non-scientific operations to outside contractors who would be better suited to develop the necessary technology.[101] The ship was accepted by the DSDP in August, 1968 and the second phase of the DSDP was carried out over the next 30 months in the Atlantic, Pacific, and Indian

[96] *supra*, Note 3, p. 219.
[97] *supra*, Note 7.
[98] *supra*, Note 79.
[99] *supra*, Note 93.
[100] *Ibid.*
[101] *supra*, Note 7.

Oceans as well as the Mediterranean and Red Seas.[102]

3.2.1 Internationalization

Although the cores had been taken from ocean basins around the world, deep-sea drilling was initially a project sponsored solely by U.S. government funding agencies. The 1970s, however, saw a change in the way that science was conducted and deep-sea drilling was no different. There was pressure to share scientific knowledge across national boundaries, especially when it involved research within the global commons. Science was becoming internationalized.

There were several major factors behind the internationalization of the DSDP. The first was the concern over the possible effect of the UN Conference on the Law of the Sea discussion on the freedom to operate in certain waters because of various claims of jurisdictional rights. The 1970s were a period of active Law of the Sea negotiations and the outcome was still uncertain. Nierenberg and others felt that international interference would be minimized if the project was supported by several nations representing the different sides in the negotiations.[103]

Another factor was the interest expressed by the international community in supporting and more actively directing the deep-sea drilling efforts. The project was already international in that nationals from several countries had participated in many of the cruises. Various scientific panels were also international. The Planning and Executive Committees, however, were completely comprised of U.S. scientists.[104]

The final major influence behind the internationalization was budgetary. The U.S. was experiencing an economic slowdown and there was concern about the level of support for science. Due to the high costs of maintaining the program many of the scientists worried that the DSDP made a very visible target for congressional budget cutting.[105]

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[102] ODP, "D/V Glomar Challenger: Drillship of the Deep Sea Drilling Project," (available at http://www-odp.tamu.edu/glomar.html, March 1998).
[103] *supra*, Note 7.
[104] *Ibid.*
[105] *Ibid.*

Interested countries were therefore offered a chance to buy into the DSDP at a cost of $1 million a year beginning in 1973. The Soviet Union, Japan, France, Great Britain, and the Federal Republic of Germany soon did so.[106] In 1976, after the addition of the five non-U.S. governments, the DSDP entered its final phase, the International Phase of Drilling. JOIDES also expanded in 1976 to include international scientists that provided scientific planning and program advice. The international partners were guaranteed the opportunity to help guide the scientific direction of the DSDP, participation in all of the cruises, and access to all of the data, samples, technical plans and specifications for equipment and techniques developed by the program.[107]

In determining that it was in their best interest to encourage international participation in the DSDP in the 1970s, the JOIDES administrators were able to establish a framework that satisfied the diverse requirements of the participants. The organizational structure of the DSDP became much more complex so that all of the collaborating nations could participate fully in the planning and execution of the drilling. This organizational structure, while not the most efficient, has ensured that the entire international deep-sea drilling community shares fully in the responsibilities and benefits of the program.[108]

It has been recognized that although extremely inefficient, international participation in the drilling programs has made deep-sea drilling scientifically broad and economically cost-effective. In addition, the basic research programs carried out by complementary basic research programs in geology and geophysics by the participating nations are a major contribution to the development of specific proposals for drilling sites.[109]

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[106] *supra*, Note 3, p. 221.
[107] *supra*, Note 4.
[108] *supra*, Note 77.
[109] *supra*, Note 4.

3.2.2 Transition from DSDP to ODP

By 1978 the U.S. component of JOIDES included ten universities and oceanographic institutions. Together these members established a non-profit corporation, Joint Oceanographic Institutions, Inc. (JOI), designed to plan and manage the geological and geophysical explorations proposed by U.S. institutions associated with deep-ocean drilling and to foster other oceanographic research.[110] In 1981 the participating institutions named JOI as the prime contractor for the DSDP.[111]

In the late 1970s it was recognized that the *Glomar Challenger* was nearing the end of her useful lifetime and that a ship with greater capabilities was needed to carry out the long-term scientific objectives of the community.[112] The *D/V Glomar Challenger* was retired in November, 1983 and the DSDP was terminated. From August 11, 1968 to November 11, 1983, over 97 km of cores were recovered from 624 sites under the auspices of the DSDP.[113]

In 1983 the Board of Governors of JOI unanimously selected Texas A&M University (TAMU) as the science operator for drilling for the proposed scientific ocean drilling program. They had received several statements of interest and capabilities from several member institutions and determined that TAMU was in the best position to carry forward the implementation of the scientific objectives developed by the international community. The selection of TAMU recognized the commitment of the university through partial funding of faculty positions assigned to the program and new physical plant facilities, the value of its large engineering faculty with special capabilities in drilling technology, the offer to negotiate an overhead rate structure as favorable as that existing under the present program, and their close association with offshore drilling expertise.[114]

Because of the economic conditions in the petroleum industry due to a world-wide

[110] *Ibid.*
[111] ODP, "Origin of the ODP," (available at http://www-odp.tamu.edu/origin.html, March 1998).
[112] *supra*, Note 4.
[113] *supra*, Note 102.
[114] JOI, draft of Advanced Ocean Drilling Program proposal, letter to Ms. Sandra Toye, Executive Officer, Office of Scientific Ocean Drilling, NSF, 11 May 1983.

drop in oil prices, a number of relatively new advanced ocean drilling vessels were available.[115] After minor modifications, these ships would be capable of carrying out the scientific objectives of the ODP. In 1983 TAMU proposed the use of the *SEDCO/BP 47*, which had been built in 1978 as a conventional oil-drilling ship. (In 1996 the *SEDCO/BP 47* was officially renamed the *JOIDES Resolution.*) TAMU arranged for the construction of new laboratories and other structures necessary for scientific ocean drilling in the fall of 1984 and drilling resumed in January, 1985.[116] The ODP was underway.

The *JOIDES Resolution* uses a dynamic-positioning system to maintain location and does so by means of 12 computer-controlled thrusters. Drilling can be done in water depths up to 8235 m and as many as 9150 m of drill pipe can be used.[117] Currently there is no blowout prevention or riser drilling capability as is standard practice in the petroleum industry to prevent dangerous levels of hydrocarbon accumulation. Extensive site surveys are done before any drilling site is approved and no proposal is accepted if there is even a remote possibility of encountering hydrocarbons.[118] If gas is detected at a drill site, the standard procedure is to remove the drill pipe immediately and the ship leaves the area as a blowout would not only have the potential to pollute a large area of the ocean floor, but the safety of the people on board the ship would also be at risk.

The organizational structure continues to evolve in order to meet the needs of a diverse scientific community and the funding agencies of nineteen nations.[119] ODP is currently funded by the U.S. NSF, the Canada/Australia/Chinese Taipei/Korea Consortium, the European Science Foundation Consortium, German, France, Japan, and the United Kingdom.[120] To date (through Leg 173, April 1997), the *JOIDES*

[115] *supra*, Note 4.
[116] *Ibid.*
[117] *supra*, Note 1, p. 5.
[118] *supra*, Note 4.
[119] *supra*, Note 77.
[120] The U.S. members of JOIDES are now: University of California at San Diego, Columbia University, University of Hawaii, University of Miami, Oregon State University, University of Rhode Island, Texas A&M University, University of Texas at Austin, University of Washington, and Woods Hole Oceanographic Institution. The European Science Foundation Consortium consists of Belgium, Den-

Resolution has drilled 1,199 holes for a total of approximately 92 miles of sediment[121] and the current U.S. funding agreements provide support until 2003.[122]

3.2.3 Democratization

While deep-sea drilling has not encountered the public scrutiny that has affected many other scientific projects, it is worth noting that the program is in fact trying to encourage more public involvement. JOIDES has established a public affairs working group in an attempt to increase the public's awareness of the program and its successes. The goal of the increased public awareness is to increase public support for the project so that it may continue to receive current levels of funding if not more.[123] Even as early as 1986, the President of JOI, Dr. James Baker, recognized the need for increased public support for the project due to the stringent levels of funding available.[124]

A panel reviewing the 1992 to 2003 portion of the ODP concluded that the ODP must advance its cause and justify its existence within the scientific community and to the educated public if it hopes to make the case to expand substantially beyond 2003. It concluded that the ODP had produced very exciting science and should therefore contribute visibly to the public understanding of science.[125]

3.3 Evaluation of deep-sea drilling

In examining the deep-sea drilling case study, it becomes apparent why the DSDP and ODP were successful where Project Mohole was not. Whereas Project Mohole did not have the support of the relevant scientific community, the DSDP and ODP have had broad support amongst geophysicists and geologists, many of whom have participated

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mark, Finland, Iceland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and Turkey.

[121] ODP, "ODP Fact Sheet," (available at http://www-odp.tamu.edu/public/factsheet.html, March 1998).

[122] *supra*, Note 77.

[123] Draft of JOIDES EXCOM Minutes, Biosphere 2, AZ, 19-20 January 1998.

[124] *supra*, Note 4.

[125] *supra*, Note 2.

in the programs.[126] These same scientists have been able to maintain almost complete control of their research program and have kept it a purely scientific project. Project Mohole became mired in politics early on and the scientific community lost all control over the direction of the research. Finally, the scientists in the DSDP focused on the scientific aspects of the research and used only technology made available to them through industry. By avoiding internal development in the beginning in areas where they were not as capable, they avoided the escalating costs that plagued Project Mohole and eventually led to its end.

In addition, the particulars that have led to the eventual success of the deep-sea drilling experiment fall into two major categories. First, and foremost, the benefits of the program have been tremendous. The early successes of the program established its reputation in the scientific and funding communities as one of extraordinary prominence and it took on a life of its own. Second, the ability of the administrators to recognize the changes in the funding climate and their flexibility has allowed them to promote their project effectively. The sections below elaborate upon the reasons deep-sea drilling has been able to endure without any significant controversy.

3.3.1 Cost/benefit analysis of deep-sea drilling

Deep-sea drilling has provided evidence for many of the fundamental earth science hypotheses that have led to scientists' current understanding of the earth. The original DSDP cruises confirmed the theory of plate tectonics and provided crucial evidence in the development of that field as the ages of ocean basins and their dynamic processes were determined. Later DSDP cruises concentrated on the nature of the oceanic crust, the sedimentary history of the passive ocean margins, and sediment dynamics along active ocean margins.[127] The early successes of this project combined with the relatively low funding levels allowed the scientists to continue and expand their efforts as the benefits of the program were tremendous. The timing of the DSDP was also fortuitous. The project was introduced at a time when the field of earth sciences

[126] *supra*, Note 7.
[127] *supra*, Note 1.

was maturing from one of empirical status to one in which substantial theories and hypotheses about major tectonic processes were flourishing. The evidence obtained by the DSDP was essential in this transition.[128]

Benefits of deep-sea drilling

The DSDP was successful from the start. On Leg 1 Site 2, core samples under a water depth of 1067 m revealed the existence of salt domes. The potential of oil beneath deep ocean salt domes is an important avenue for commercial development and oil companies had yet to venture into deeper waters. Because the purpose of the DSDP was scientific exploration, however, oil companies were given samples only after agreeing to publish their analyses.[129]

In 1962 Harry Hess had submitted an "Essay in Geopoetry" to the ONR which detailed his ideas of seafloor spreading and substituted the theory of plate tectonics for the theory of continental drift,[130] supporting the ideas previously set forth by W. Jason Morgan and Xavier Le Pichon.[131] While many geophysicists came up with evidence of plate tectonics in the form of magnetic reversals and seismological records that supported Hess's claims, most geologists wanted confirmation from the paleontological data that only deep-sea drilling could provide. Because of this, one of the first projects undertaken by the DSDP (Leg 3) was the drilling of 17 holes at 10 different sites across the Mid-Atlantic Ridge in the South Atlantic Ocean. Working in water depths of 2.1 to 4.7 km, the drill crews penetrated the entire sedimentary column and brought back a wealth of information. The paleontological evidence was overwhelming. Within one year of commencement and about $15 million, the DSDP had provided definitive proof of concept for seafloor spreading and plate tectonics.[132] The theory of plate tectonics has revolutionized the field of geophysics and its confirmation was the pivotal point in the understanding of the dynamic processes of the

[128] *supra*, Note 93.
[129] *supra*, Note 102.
[130] *supra*, Note 3, p. 209.
[131] *supra*, Note 102.
[132] *supra*, Note 3, pp. 220-221.

earth.

Since then, deep-sea drilling has also provided data on a variety of Earth's basic processes. Scientists from a variety of disciplines use the cores to learn about the evolution of life in the sea, the temporal nature of global climate, ocean currents, and Earth's magnetic field, to name a few. DSDP cores in the Mediterranean showed conclusively that the Straits of Gibraltar had been shut off twice in recent geologic times, an effect of sea level change.[133] One of the ODP's earliest accomplishments was to demonstrate that fluids move through rocks at continental margins as well as at highly fractured mid-ocean ridges.[134] The ODP has also drilled into sedimentary deposits that contain long and extremely detailed records of climate change. This sedimentary record provides an opportunity for scientists to study climate oscillations at high frequencies over a long period of geologic time so that subdecadal-scale events, such as the El Niño Southern Oscillation, can be examined.[135]

In addition to the scientific achievements, the DSDP was accompanied by many advances in deep-sea drilling technology. In addition to overcoming problems of drilling in deep waters and penetration into basaltic layers, the DSDP was the first to solve the problem of replacing worn drill bits and threading the corer back into the same drill hole for deeper penetration. This was accomplished by using sonar scanning equipment and a re-entry cone with a larger diameter than the actual drill hole.[136] In addition, in 1979 the hydraulic piston corer was introduced and virtually undisturbed cores of the soft sediment layers could be obtained. Through the accumulation of knowledge from this project and the advances in coring ability, new areas of research became available and the physical and chemical characteristics of the ancient oceans were suddenly obtainable by 1980. The entire paleoceanographic community now had a completely new data set with which to work at a time when the history of the earth was becoming of great interest.[137]

[133] *supra*, Note 79.
[134] *supra*, Note 80, p. 28.
[135] *supra*, Note 80, pp. 20-21.
[136] *supra*, Note 102.
[137] *supra*, Note 1.

Costs of deep-sea drilling

A discussion of the benefits cannot neglect the costs of the program. The ODP is currently funded at about $45 million/year, up from $35 million in 1986.[138] A large fraction of this is covered by U.S. funding agencies with the remainder divided up between the international partners. So far, this level of support has been deemed appropriate for the results that have been obtained. The challenge will come in 2003 when the desired funding level triples.[139]

While ODP will expire in 2003, the international drilling community will not have exhausted the potential of deep-sea drilling and plans are currently being developed to continue the deep-sea drilling and coring under a new program currently known as the Integrated Ocean Drilling Program (IODP). The necessary funding levels for this expanded program are expected to be three times that of current funding and an intense effort to increase the level of international participation is now underway.[140]

Japan is expected to assume an international financial leadership role matching that of the United States in 2003 so that the IODP may acquire a drilling vessel with riser drilling capability in addition to a *JOIDES Resolution*-type ship.[141] Riser drilling capability is needed to prevent the possible blowouts and serious damage to the environment that has kept the DSDP and ODP from drilling in potentially dangerous areas. Japan has taken a lead in the acquisition of this technology as most of the area around Japan has been off-limits to the DSDP and ODP because of the presence of hydrocarbons. Blowout prevention capability would allow Japan to accomplish many of its scientific objectives without the risks associated with drilling near hydrocarbon deposits.[142]

Even with the addition of Japan as an equal funding partner to the U.S., the success of the IODP depends on the additional commitment of funding agencies and scientists from institutes and universities around the world. The German represen-

[138] *supra*, Note 123.
[139] *supra*, Note 77.
[140] *Ibid.*
[141] *supra*, Note 80.
[142] *supra*, Note 77.

tative to the JOIDES Executive Committee complained in a 1998 meeting that the program is already suffering because partners are not able to meet or increase their levels of contribution.[143] JOIDES is currently soliciting new countries to join as associate partners and is attempting to encourage the already participating nations to contribute more. The future success of the program will depend entirely on their success at increasing the amount of available funding.[144]

Risks of deep-sea drilling

The primary risks associated with the project involve the safety of the scientists and crew aboard the research vessel and the destruction of the environment in the neighborhood of the drilling sights. Both of these concerns are legitimate and are addressed through the proposal acceptance mechanism. The safety of the people involved in the coring is of utmost importance. No proposals are accepted if there is considered to be any risk of danger to the ship or its personnel.[145] The extensive site surveys that are conducted at proposed drill site locations are done in part to determine the possibility of such a risk. Fortunately, there have never been any major incidents where lives have been in danger as it would only take one accident to tarnish the image of the entire program.

The risk of environmental damage is primarily that due to the potentially extensive pollution problem near the drill site that would occur should there be a blowout. Again, the extensive site surveys are done in part to avoid this risk. Although the drilling is done far from land and evidence of an oil spill would be unlikely to show up along any coastlines resulting in less publicity than a standard oil spill, the amount of damage that could ensue is an unknown quantity and the drilling community would like to avoid it at all costs.

Although there have been no major incidents with hydrocarbon blowouts, there is also the potential for environmental damage through normal drilling operations

[143] *supra*, Note 123.
[144] *Ibid.*
[145] *supra*, Note 77.

and deep-sea drilling has caused some damage to the ocean floor. When drilling first started in the 1960s, the ocean floor was considered to be a desert - devoid of any life. It is now known that the ocean floor can sustain highly diverse communities of marine life under certain circumstances. Not only does drilling create large holes in the bottom of the ocean and disturb the benthic community, on one occasion the drilling actually created a new hydrothermal vent thereby significantly altering the biological community in the surrounding area.[146]

3.3.2 Flexibility of the administrators

While deep-sea drilling has always been proposal driven,[147] the management has been extremely adept at recognizing and adapting to the changes in the political, and therefore funding, climates. This has been true not only in their organizational structure, but also in how they present the results of their research to establish support for future funding.

The ability to recognize and meet the needs of the changing requirements of funding agencies is a difficult task. The U.S. Congress has consistently promoted the need for funding of basic research although applied research is much easier to justify. Deep-sea drilling has been able to promote itself almost entirely on its basic research merits within the United States and has established itself as science for science's sake. In Great Britain, however, the trend has turned towards support for science for society's sake and the results of deep-sea drilling are couched in terms of their benefits to society when presented to the decision makers there.[148]

In addition to being flexible in terms of how the project is presented to funding agencies, the project managers have also remained flexible in terms of project objectives. The goals of the DSDP and ODP have changed with the evolution of the science as more information became available on the dynamics of the earth. The transition from the DSDP to the ODP occurred at about the same time a transition

[146] *Ibid.*
[147] *Ibid.*
[148] *Ibid.*

in project goals was taking place. The ODP was able to pick up where the DSDP had left off and revitalized the project with a new set of objectives. Recently, emphasis has been put onto the evidence of environmental conditions of the ancient oceans and of climate changes through time because of the enhanced public and scientific interest in problems of global change.

This flexibility in project goals while still maintaining the program's overall mission has allowed deep-sea drilling to endure the political and sociological changes that affect funding levels and support for the project. The scientists planning the long-range objectives for IODP are taking this into consideration as they develop the scientific plan. They are intent on improving the available technology so they can move into areas that have recently become of interest. In addition, they are establishing goals that are based across a broad range of scientific issues that will provide practical benefits to society as they seek to better understand the complex earth system.[149]

[149] *supra*, Note 80.

Chapter 4

Acoustic Tomography

While deep-sea drilling has incurred almost no public scrutiny, this next area of research includes the benchmark example of public involvement in oceanographic research. This chapter is devoted to a description of two experiments utilizing acoustic tomography, the use of sound to measure the average ocean temperature between two points, and the public scrutiny they faced. One of the experiments in particular, the Acoustic Thermometry of Ocean Climate (ATOC) Experiment, came under an intense public scrutiny that grew into an emotionally charged battle over the fate of the experiment. This experiment, therefore, is emphasized throughout the chapter while the other experiment, the Heard Island Feasibility Test (HIFT), was a precursor to ATOC and is also included to set the stage for the introduction of ATOC.

The controversy that developed over ATOC was framed by a debate over the potential impact of the experiment on marine mammals versus the benefits of better climate change information that the experiment could produce. This debate took place on three distinct levels:

1. Many in the scientific community thought that the problem was poorly framed for the data that would be generated. There was not only debate among scientific disciplines, there was also debate within the physical oceanography community as to whether data provided by acoustic tomography would actually be

relevant to the question of global warming.[150] In addition, while many marine biologists felt strongly that the project would not generate enough new data to warrant the risks to the health of marine mammals, others thought that the risks would be miniscule.[151] There is still debate within the scientific community as to the scientific value of the project.[152]

2. Many environmental groups felt that global warming has already been confirmed and that another (expensive) research program that would just restate what is already known would not be prudent – especially in light of the potential environmental impact.[153]

3. A few groups were concerned that if the temperatures in the Pacific Basin were shown to cool over the next decade, ATOC would provide policy makers a false-negative on the existence of global warming and give them an excuse not to take measures to mitigate climate change. These groups did not want the health of the marine mammals to be put at risk in exchange for information they felt would be misused.[154]

The controversy was then exacerbated by the persistence of misinformation, mistrust, and a poor execution of the democratic process on both sides of the debate.[155] More so than any other oceanographic research that preceded it, ATOC faced a public scrutiny that eventually had a great impact on the work that the scientists were finally allowed to conduct.

Whereas deep-sea drilling exemplified the internationalization of oceanographic research and the positive effects that this transition had on the quality and character of the science, ATOC is one of the best examples of the democratization of oceanogra-

[150]Gibbons, A., "What's the sound of one ocean warming?" Science, 248, 6 April 1990, pp. 33-34.
[151]Shurkin, J., "Pacific sound experiment faces heat," Nature, 368, 7 April 1994, p. 485.
[152]Baggeroer, A., Professor of Engineering, MIT Department of Ocean Engineering, Personal communication, April 1998.
[153]Stiff, H., "ATOC pudding: Recipe for a global warming experiment," *Wave-Length*, May 1994.
[154]GWF, "ATOC military-environmental technology: "Dual Use" or DOUBLE SPEAK ?" Perspective and Commentary from Great Whales Foundation, 10 October 1995, (available at http://elfnet1a.elfi.com/gwfPerspective.html, April 1998).
[155]*supra*, Note 12, pp. 55-59.

phy and the potential effects, both positive and negative, of this transition. Because this case study was chosen as an example of how public scrutiny can change the direction of the scientific work, the description of the research will be separated into two sections. The first section of the chapter is an account of the development of the experiment, including the HIFT, and the details of the research as it was originally intended. The second section is devoted to the controversy caused by the experiment and the modifications that this controversy effected in the design of the experiment.

In addition to a description of the experiments and the events leading to the emotionally-charged controversy over ATOC, this chapter also includes an analysis of the actions and reactions of the scientists with regard to the public. The third section of the chapter analyzes the interaction between the scientists and the public within the democratic process and the characteristics of this interaction that served to both interfere with as well as promote the research. The extreme negative reaction of the public to ATOC took the scientists completely by surprise and many mistakes were made in the attempts to push the experiment ahead as planned. Those elements that created misunderstanding and controversy as well as those that facilitated the progress of the research will be drawn out in preparation for the development of the policy protocols in Chapter 6.

4.1 The proposed Acoustic Thermometry of Ocean Climate experiment

Acoustic tomography is a signal processing technique developed by Dr. Walter Munk of SIO and Dr. Carl Wunsch of the Massachusetts Institute of Technology in the 1970s that detects changes in ocean temperatures by measuring the travel time of low-frequency sounds (< 100Hz) transmitted across large distances.[156] The wide geographic and year-round coverage that acoustic tomography can provide has encouraged scientists to present it as a tool that can provide much more accurate data

[156] Yam, P., "The man who would hear ocean temperatures," *Scientific American*, January 1995, pp. 38-40.

than other conventional means of measuring global temperature trends. Because this technique integrates temperature variations over a large region, the smaller scale turbulent and internal-wave features that usually dominate point measurements are averaged out and the large-scale dynamics can be better determined.[157]

Acoustic tomography uses a phenomenon known as the deep sound channel or the SOund Fixing And Ranging (SOFAR) channel. This channel is defined by the depth at which the sound speed in water is a minimum and occurs at an average depth of one kilometer. The speed of sound in water is a strong function of both temperature and pressure. As the temperature of the water decreases with depth, the speed of sound also decreases. Eventually the pressure effect compensates for the decreasing temperature and the speed of sound increases deeper in the water column, thus producing a sound speed minimum at an intermediate depth. The paths that sound waves take in the ocean are determined by reflections off the ocean surface and bottom and by changes in the sound speed along the paths. Because the sound waves are bent away from the surface waters and also from the deep waters, they become trapped at the depth of the sound speed minimum. This channel allows sound energy to travel long distances through ocean basins without the scattering from the rough ocean surface and bottom that results in energy loss.[158]

Although travel times must be measured to a nominal accuracy of 1 millisecond, tomographic transmissions consist of long coded signals lasting 30 seconds or more. These transmissions are audible near the source, but over most of the ocean they are below ambient noise levels, requiring sophisticated spread-spectrum signal processing techniques to recover them.[159] The acoustic tomography experiments that are now described attempt to use this technology as a tool to obtain better information on large-scale ocean dynamics.

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[157] WHOI Ocean Acoustic Lab, "Ocean Acoustic Tomography at WHOI," available at http://www.oal.whoi.edu/tomo2.html, April 1998.
[158] *supra*, Note 9, pp. 27-28.
[159] *supra*, Note 157.

4.1.1 Heard Island Feasibility Test

In 1960, 130 kg of TNT were detonated off the coast of Perth, Australia. Approximately 3.7 hours later, the sounds generated by the detonation were detected by hydrophone receivers near Bermuda, nearly 20,000 km away. Munk reinterpreted the Perth-Bermuda test in 1988 and proposed that sound could be used to measure basin-scale temperature changes.[160] This proposal resulted in the HIFT, a test to assess the feasibility of acoustic tomography for long-range monitoring of ocean temperatures and therefore verification for global climate models.[161]

The HIFT was conducted from 26-30 January, 1991 off the coast of Heard Island, an uninhabited island located near Antarctica between Africa and Australia. The scientists had access to U.S. Navy transducers whose operational use was limited to a maximum depth of 300 m so the location was ideal because of the local sound channel's close proximity to the surface (175 m) as well as the multiple, unimpeded paths to receiving stations on both U.S. coasts.[162] The initial plan depended on existing U.S. Navy bottom-mounted receiver arrays at Bermuda and both coasts of North America.[163] During the planning stages of the experiment, however, several scientists from around the world offered to take receivers out to sea to listen to the transmitted signals. Although HIFT was jointly funded by the Department of Energy, NOAA, NSF, and ONR for approximately $1.7 million,[164] the final result was an informal collaboration between scientists from nine countries[165] using a diverse set of receiving systems.[166]

HIFT transmissions were made on a pre-selected fixed schedule of one hour of continuous transmission followed by two hours of silence for the entire test period from

[160]Munk,W., W.C. O'Reilly, and J.L. Reid. "Australia-Bermuda sound transmission experiment (1960) revisited," J. Phys. Oceanogr., 18, 1988, pp. 1876-1898.
[161]*supra*, Note 10.
[162]Munk, W., R.C. Spindel, A. Baggeroer, and T.G. Birdsall, "The Heard Island experiment," J. Acoust. Soc. Am., 96(4), 1994, pp. 2330-2342.
[163]*Ibid.*
[164]*supra*, Note 11.
[165]The nine countries involved in HIFT were Australia, Canada, France, India, Japan, New Zealand, Russia, South Africa, and the U.S.A.
[166]*supra*, Note 162.

the *R/V Cory Chouest*. During any one transmission, the signal was broadcast from five of the ten acoustic sources mounted on a vertical array at 175 m below the surface. The sound source produced a maximum *in situ* source level of 221 dB centered at a frequency of 57 Hz with a bandwidth of about 14 Hz and was of sufficient strength that it was detected across five ocean basins. The experiment had been originally planned to last for 10 days, but the onset of a gale terminated the transmissions after only 35 transmissions.[167]

Due to the unknown effects of anthropogenic sounds in the ocean environment, various researchers and environmental groups were concerned that marine mammals might be harmed as a result of the experiment. Some marine mammals use low-frequency sound in feeding, navigating and communicating and the addition of such noise into the ocean environment could be cause for caution.[168] After first learning of HIFT in *Science* nine months before the proposed experiment, the executive director of the Marine Mammal Commission (MMC) voiced his concerns to NOAA. Five months before the experiment was scheduled to begin, NOAA decided to get scientific feedback about HIFT's potential for harming marine life.[169] As a result, NOAA and Australia's Department of Environment both determined that full environmental impact statements were not required,[170] but permits were deemed necessary by NMFS and Australia's National Parks and Wildlife Service[171] because they concluded that the data were insufficient to determine the extent to which the transmitted sound could possibly affect marine mammals.

The original HIFT experiment needed an "incidental take" permit under the MMPA, but such a permit usually required a minimum of one year to issue. A biological component was then added to HIFT so that a permit to conduct scientific research that would benefit the animals could be obtained. This permit typically required only four months to process.[172] A U.S. scientific research permit in accor-

[167] *Ibid.*
[168] *supra*, Note 12, p. 14.
[169] *supra*, Note 11.
[170] Anderson, I., "Global hum threatens to 'deafen' whales," *New Scientist*, 19 January 1991.
[171] *supra*, Note 162.
[172] *supra*, Note 11.

dance with §104(c)(3) of the MMPA was approved by the NMFS after a 30-day public review period and consultation with the MMC.

The objective of the marine mammal portion of HIFT was to determine potential short-term impacts on marine mammals. The study was to determine if marine mammals react adversely to the transmissions by monitoring the following conditions prior to, during, and after each transmission: (i) vocalization rates; (ii) respiration rates (i.e. surfacing); and (iii) the direction of swimming.[173] Even though the marine mammal research was added to HIFT only a few months before the actual experiment, it was determined to be an essential component of the overall experiment.[174]

Although the marine mammal component of HIFT was limited due to its lack of resources and time, the observers were able to conclude that there were no visible signs of permanent damage to any local marine life.[175] The marine mammal assessment and monitoring program was conducted before and during the sound transmissions in accordance with the NMFS permit and MMC recommendations. Visual and hydrophone observations began four days prior to HIFT from the *R/V Amy Chouest* to establish relative abundance and distribution of marine mammals in the study area. Surveys were conducted during the transmissions to assess the effects of HIFT on local marine mammals.[176] Transmissions were to be suspended if marine mammals were sighted or heard within one kilometer of the source vessel, marine mammals were sighted or heard within the area ensonified at a level of 160 dB or greater (about 1.1 kilometer from the source vessel), or any marine mammals were injured. In the event of an injured animal, the entire experiment would be suspended until the experimental protocol could be reviewed and revised by NMFS under consultation by the MMC.[177]

The success of HIFT was twofold. Not only was the sound signal transmitted al-

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[173] *supra*, Note 12, p. 32.
[174] *Ibid.*
[175] Bowles, A.E., M. Smultea, B. Würsig, D.P. DeMaster, and D. Palka, "Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test," J. Acoust. Soc. Am., 96(4), 1994, pp. 2469-2484.
[176] *Ibid.*
[177] Buck, E.H., "Acoustic Thermometry of Ocean Climate: Marine mammal issues," CRS Report for Congress, 95-603 ENR, 12 May 1995.

most 18,000 km, but no marine mammals were visibly harmed. A successful feasibility test was regarded by the scientists to be a necessary, but not sufficient, prelude to expanding the ocean acoustic tomography effort.[178] Because the concept that sound could propagate across ocean basins had been established through HIFT, scientists then began to develop an experiment that would test whether or not the arrival times of such signals could be determined at the precision needed to be useful in detecting trends in temperature changes. Upon returning from Heard Island, the HIFT scientists initiated the planning for the follow-up experiment, the Acoustic Thermometry of Ocean Climate Experiment, in the Pacific. While a permanent sound source was originally planned for Heard Island if HIFT proved to be successful,[179] the remote location of Heard Island as well as local oceanographic properties made the site inadequate for future research.[180]

4.1.2 Acoustic Thermometry of Ocean Climate

ATOC, originally intended to be a two year feasibility study that was proposed to test existing climate models,[181] is currently in progress. Although eleven institutions from seven nations are involved, it is funded primarily by the U.S. Department of Defense through the Strategic Environmental Research and Development Program (SERDP) with sponsorship by the Advanced Research Projects Agency.[182] ARPA is mandated by Congress to invest in environmentally relevant issues and is therefore interested in ATOC because of its implications for monitoring global warming.[183]

The technology and goals of ATOC are an extension of HIFT. While HIFT was a test to determine the feasibility of detecting sound transmissions across long distances throughout ocean basins, ATOC is a test to determine whether such a technique is capable of producing high quality data on oceanic properties. In order to increase the

[178] *supra*, Note 162.
[179] *supra*, Note 150.
[180] *supra*, Note 162.
[181] *supra*, Note 12, p. 33.
[182] *supra*, Note 177.
[183] *supra*, Note 153.

accuracy of the information collected, two sound sources are in use. Originally, one was to be located 15 km off the coast of Kauai, Hawaii in 850 meters of water, and the other 40 km off the coast of Point Sur, California in the Monterey Bay National Marine Sanctuary.[184] The California location was chosen because of the proximity of the sound channel to shore and the presence of Naval hydrophone arrays and of land-based support facilities. An array of passive Naval hydrophone arrays throughout the North Pacific and other hydrophone arrays near New Zealand, Point Sur, and Adak, Alaska receive the signal at distances of 3,000-6,000 km.[185]

Because of the results of the Heard Island experiment, the ATOC scientists determined that a lower sound intensity could be used at basin-scales and decreased the intensity from about 210 dB to 195 dB and increased the frequency from 57 Hz to 75 Hz with a broader bandwidth of 35 Hz on a schedule of one 20 minute transmission every four hours. The lower intensity of the transmissions and the deeper position of the SOFAR channel were also expected to decrease the intensity in the biologically important upper ocean by more than 30 dB relative to HIFT.[186]

In addition to the acoustic tomography portion of the project, there was also a marine mammal component, the Marine Mammal Research Program (MMRP). The principal investigators had learned their lesson from HIFT and proposed to monitor marine mammal reactions to the sound transmissions throughout the duration of the experiment. $2.9 million was devoted to biological studies aimed at gathering data on how undersea sounds affect the long-term health and behaviour of many species.[187]

[184] *supra*, Note 177.
[185] *Ibid.*
[186] *supra*, Note 162.
[187] Schmidt, K., "ATOC delayed as report laments research gaps," *Science*, 264, 15 April 1994, pp. 339-340.

4.2 The existing Acoustic Thermometry of Ocean Climate experiment

In February 1994, during the public comment period for the ATOC permit applications, a controversial message was sent out over MARMAM, the internet discussion group for marine mammologists. The message stated that ATOC would cause tremendous irreparable consequences to marine mammals and called for opposition to the project. Although based on the incorrect scale for measuring sound in water (The author did not take into account the $O(10^6)$ decrease in intensity from dB in air to dB in water.), the information was rapidly disseminated throughout the marine biological community.[188] Following this initial incident, on March 24, 1994, the Los Angeles Times reported that 677,000 marine mammals would be "taken" and that a "deaf whale is a dead whale." The article implied that 677,000 marine mammals would be killed as a result of the experiment.[189]

Not surprisingly, the proposed ATOC experiment became subject to an unprecedented amount of negative publicity and became the focus of an emotional debate. As a result, the experiment was delayed by 18 months, the initial project design was dramatically altered, and over $1 million of the project funds were spent on attorneys' fees.[190] The details of the experiment that created the conflict are first discussed and then the changes that were made to the original experimental design through a series of meetings between the constituents are described in this section. An analysis of the scientists' role in the controversy will be carried out in the following section.

Again, the controversy was primarily over the risk to marine mammals weighed against the benefits of better climate information and was debated at three distinct levels. Because the effects of anthropogenic sound on marine mammals in the ocean are not well understood, much of the debate was among scientists. This lack of knowledge was at the core of the debate between the opponents and the proponents

[188] *supra*, Note 12, p. 55.
[189] *Ibid.*
[190] *supra*, Note 12, pp. 37-38.

of ATOC as neither side had sufficient evidence to prove the potential for harm or the lack thereof. While the experiment was presented as an ideal opportunity to learn more about global climate change, many environmentalists felt that global warming had already been confirmed and that the potential for any additional information did not outweigh the possibility of negative impacts on marine mammals and other biota.[191] In addition, many felt that because previous tomographic experiments that had looked at trends in ocean temperatures had found a recent decrease in core temperatures, ATOC would produce a false-negative with regard to global warming and would not produce data that should be used in determining national policy.[192]

The controversy was fed by many misunderstandings of facts and definitions by scientists and the public. The field of acoustics is highly technical and statements by qualified scientists can easily be misinterpreted by the media and therefore the public. As was previously mentioned, the intensity scale used for sound in the ocean is different from that used in air. Because of the difference in scales and due to the fact that water is a better conductor of sound than air, the intensity of 120 dB in air is equivalent to an intensity of 181.5 dB in water. This difference is 61.5 dB on a logarithmic scale and a factor of more than 1,000,000 on a linear scale.[193]

The terms used by scientists and public agencies also proved to be misleading. Whereas the MMPA defines the term "take" to mean "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal," the general public is not aware of the specific meaning of "take" within the context of NMFS permits. When the media reported that ATOC scientists had been given a permit to "take" 677,000 marine mammals, the public outcry was understandable.

The location of the sound sources was another source of contention. The California source was originally sited in the Monterey Bay National Marine Sanctuary, a prime feeding and breeding ground for several marine mammal species.[194] The Hawaii source

[191] *supra*, Note 153.
[192] *supra*, Note 154.
[193] Urick, R.J. Principles of Underwater Sound 3rd ed., McGraw-Hill, Inc., New York, NY, 1983, 423 p.
[194] *supra*, Note 187.

was also located near the seasonal feeding grounds of gray whales. The positioning of the sources was a source of contention for many environmental groups who felt that the technical aspects of the project were being valued more highly than the environmental concerns. Ironically, the MMRP supported the Monteray Bay Sanctuary site as it would have provided more marine mammals to observe.[195]

Several meetings between constituent groups and input from public hearings generated more changes in the experimental design. The major change was the transfer of control of the transmissions from the acoustic tomography group to the MMRP. Signals would only be produced when the sea conditions were satisfactory for scientific observers to document any changes in the distribution of behaviour of marine mammals within 1 km of the sound source. The MMRP thus became the primary focus of ATOC for the first 18 months. The acoustic climate measurement was put on hold until the MMRP could evaluate the data regarding the response of marine mammals to the ATOC sound source and determine whether an acoustic experiment would be viable.[196]

Most of the modifications made to the ATOC experiment were concessions to the concerns over the well-being of the marine mammals. These modifications include:

- A ramping up of the intensity of the sound source over five minutes before the twenty minute full power transmission to warn marine fauna of the approaching transmission;
- A decrease in the source intensity from the proposed 195 dB to 185 dB for the first six months with a possible increase to 195 dB after that, depending on the reactions of marine organisms;
- A reduction in the transmission schedule from twenty minutes every four hours each day to twenty minutes every four hours every fourth day;[197]
- A transfer of the transmitter out of the Monterey Bay National Marine Sanctu-

[195] *supra*, Note 12, p. 43.
[196] *supra*, Note 12, pp. 41-45.
[197] *supra*, Note 12, pp. 42-43.

ary to the Pioneer Seamount, approximately 88 kilometers west of Point Pillar, California in 980 meters of water after the Sanctuaries and Reserves Division of NOAA disproved of the original location. [198]

In addition to the modifications in the experimental design, because of the delay to the project there was a substantial amount of potential data lost because of the finite lifetime of instrumentation that had already been deployed before the project was put on hold. Several large-aperture vertical line arrays designed to resolve vertical modes up to mode 10 had been built to better understand the modal distribution that is required for the interpretation of long-range transmissions.[199] These arrays were useless by the time transmissions actually started and were too expensive to replace.[200]

It is necessary to note that although many changes were made to the original experiment and the acoustic tomography component of the experiment may suffer because of these changes, not all of the changes were detrimental to the science being carried out under ATOC. In particular, the emphasis on the marine mammal component of ATOC instituted an actual experiment on marine mammals and sound instead of a mere monitoring program. This type of research could generate useful data on marine mammal reactions to sound that could reduce the uncertainties for future acoustic research.

4.3 ATOC and the democratic process

The previous sections described much of the controversy generated by HIFT and ATOC as well as the effects the controversy had on the direction of the original experiments. This section examines the factors that led to such an inappropriate execution of the democratic process and discusses the actions of the ATOC scientists and the public that served to both interfere with as well as promote a more constructive

[198] *supra*, Note 177.
[199] *supra*, Note 162.
[200] *supra*, Note 152.

public involvement.

Before the scientists' role in this debate is discussed, however, it must be made clear that the goal of the democratic process in science should not be a consensus on the scientific method, but rather a consensus on the responsibilities of the scientists when conducting research that involves some degree of risk to a public good, i.e. the oceans. Because of the uncertainties in evaluating risk and perceived risk, the debate can become focused on the value of the scientific data. The real issue is not the certainty of the data, however, but rather what the weighting of those uncertainties should be. It is in this weighting process that the values of the public must be considered.

An effective democratic process depends on two basic conditions: 1) all of the relevant stakeholders must be active participants from the planning stages through to a final analysis of the results and 2) there must be a solid foundation of trusted information that is shared by everyone. Once these conditions have been met, constructive multiparty, multi-issue discussions can proceed. Unfortunately, behaviour on all sides worked against an effective debate.

Lack of appropriate participation

The democratic process is only effective if all of the relevant stakeholders are active participants. The public scrutiny took ATOC scientists by surprise. Even though HIFT generated controversy, the scientists had predicted that the marine mammal issue would not be nearly as critical in ATOC because of the smaller scale of the research and the lower sound intensities.[201] Instead of applying their experiences from HIFT toward a concentrated effort to mitigate potential controversy in ATOC, the scientists assumed that the risks to marine mammals were no longer an issue as HIFT had not shown any visible signs of permanent damage. The issues that had been raised before HIFT, however, had not been resolved. There was still a lack of hard data on the long-term effects of loud, low-frequency sound on marine mammals

[201] *supra*, Note 11.

and the proposed ATOC experiment had the potential to affect thousands of animals.

The democratization of science is a new paradigm and one not openly embraced by most scientists. The ATOC scientists are no exception. Instead of acknowledging the concerns of their opponents and inviting public comment, the ATOC scientists dismissed the concerns and were frustrated that their research might be cancelled for "no good scientific reason."[202] Scripps did send out public announcements in attempts to combat the misinformation that plagued their experiment,[203] but their participation in a public discussion of ATOC did not occur until a series of hearings sponsored by the NMFS just before the experiment was initially scheduled to begin.[204]

In addition, while the public were willing participants in the process, many were irresponsible in their behaviour. The scientists were insulted and physically threatened by several individuals.[205] Opposing viewpoints are a necessary component of debate, but if not voiced in an appropriate manner they add nothing to the discussion.

A lack of trusted information

The democratic process was also burdened with misinformation and misperceptions resulting in strong opinions based on incorrect information. Much of this incorrect information could have been prevented, or at least mitigated, by the ATOC scientists.

While much of the controversy in ATOC was initiated by the dissemination of incorrect information regarding the intensity of the ATOC sound sources by a non-ATOC scientist, the ATOC scientists could have provided better information about their research before the public comment period. Scripps did send out a press release in 1993, announcing the experiment, but the release was printed in only a few newspapers and did not mention the marine mammal component or the potential harm to marine mammals.[206] Not only was the information not guaranteed to reach the relevant stakeholders, but it was also incomplete. The method of informing the

[202] *supra*, Note 151.
[203] *supra*, Note 12, p. 41.
[204] *supra*, Note 151.
[205] *supra*, Note 152.
[206] *supra*, Note 12, p. 59.

public through carefully worded press releases is too uncertain a strategy to use for such purposes.

The experiment was also not presented in the best possible light from the beginning. Instead of being presented as an experiment with the potential for producing extraordinary types and amounts of information about the oceans never before collected, the acoustic experiment was initially presented as a method to detect global warming.[207] It was not until after the ATOC controversy was underway that the experiment was presented for what it really was, an attempt to verify climate models[208] as well as a strategy for collecting other important oceanographic information.

The public also began to distrust the scientists themselves. Dr. Walter Munk has been described as a "consummate salesman."[209] This was not the approach that was needed in ATOC when dealing with the public in a highly emotional controversy. A balanced and transparent presentation of the information needs to be given to the public so that they trust the scientists and the information that is given to them.

There were also misperceptions that the ATOC scientists had relatively no control over. Several environmental organizations, for example, concluded that there were military implications associated with ATOC because it receives its funding from the DOD through SERDP.[210] Although there is no military component to the project, the DOD funding source will always lead some people to distrust the motivation behind the research.

While it is clear that the ATOC scientists were taken by surprise by an intense public scrutiny, they cannot escape all responsibility for the controversy and the resulting negative consequences. The scientists had the opportunity to learn from their HIFT experiences and become active participants in a public debate. Instead they assumed that the problems that had surfaced in HIFT had vanished and they then became the defendants in a public trial. A better awareness of the potential for conflict and an appropriate proactive public outreach could have mitigated much of

[207] *supra*, Notes 150, 187, and 11.
[208] *supra*, Notes 156 and 152.
[209] *supra*, Note 156.
[210] *supra*, Note 154.

the controversy that has damaged the integrity of their research.

Chapter 5

CO_2 Sequestration

The third and final area of research demonstrates the new awareness of marine scientists to the increased public scrutiny they may encounter in their work. While skeptical attitudes towards public involvement may not have significantly changed, scientists are at least now recognizing that a concentrated effort at public outreach in the early stages of their research may improve their chances at successfully withstanding an intense public scrutiny.

This final case study describes a CO_2 ocean storage field study. It is the first step in a progression of experiments that are being planned to determine the feasibility of a serious attempt to sequester CO_2 in the oceans. What makes this experiment significant for this discussion is that the principal investigators for the CO_2 ocean storage field experiment have recognized that local acceptance of the project will depend strongly on public outreach efforts.[211] In addition, it is also well understood that the viability of ocean CO_2 sequestration as a greenhouse gas mitigation option may ultimately depend on social and political considerations and that societal acceptance can only occur if the public is included in the ongoing research and debate.[212] The experiment, therefore, includes a public outreach component, something completely foreign to most of the principal scientists.

[211] Adams, E. and H.J. Herzog. "Site Selection Study for an Ocean CO_2 Disposal Field Experiment," MIT Energy Laboratory report, Cambridge, MA, February 1998.

[212] Adams, E.E. and H.J. Herzog, "Environmental Impacts of Ocean Disposal of CO_2: Volume 1 - Executive Summary," MIT Energy Laboratory report, Cambridge, MA, December 1996.

Because it is nearly impossible to separate this feasibility study from the implications of large-scale ocean storage of CO_2, this chapter emphasizes the details of the one experiment within the context of the larger problem. The first section of this chapter, therefore, is devoted to the motivation behind the field experiment as well as the overall effort to investigate CO_2 mitigation options. The second section will describe the experiment itself. Since the experiment is still in the planning stages, many of the details have not yet been finalized. Instead, the general structure of the experiment will be discussed. The third section then looks at potential barriers to the implementation of the experiment. These barriers come mostly in the form of potential opposition to the experiment as opposed to technical or scientific obstacles. Because of this, the final chapter of this thesis will use the CO_2 sequestration experiment as a model for the application of the policy protocols designed to effectively integrate the public. Before moving to the final chapter however, a description of the public outreach efforts to date will be discussed in the fourth section of this chapter. These efforts will then be used as a starting point for the application of the policy protocols.

5.1 Motivation

The motivation for this experiment comes from the drive to find options to reduce atmospheric CO_2 levels. Because of potential adverse effects on the global climate due to increased concentrations of greenhouse gases such as CO_2, the world community is pushing measures to mitigate these effects. The United Nations Framework Convention on Climate Change (UNFCCC) is at the center of international efforts to combat global warming. Adopted in 1992 at the Rio Earth Summit, its ultimate objective is "the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."[213] In promoting this objective, the Convention calls for states to develop action plans to reduce their anthropogenic emissions of CO_2 and other greenhouse gases to below their 1990 levels by the year 2000.[214]

Since the Convention, in the efforts to find mechanisms to reduce atmospheric CO_2 levels, there have been several principal mitigation options suggested: 1) greater conversion efficiency and fuel switching within the fossil fuel sector, 2) greater reliance on non-fossil fuel energy sources, 3) greater energy conservation and end-use efficiency, 4) geo-engineering options to reflect solar radiation or increase CO_2 uptake by phytoplankton or forests, and 5) methods to capture, and utilize, convert or store CO_2 before emission to the atmosphere can take place.[215] The first four responses to global climate change include many relatively low-cost CO_2 mitigation technologies that are sometimes termed "least regrets" as in theory they not only reduce emissions of greenhouse gases but provide benefits to society as well. Many scientists also suggest that such actions might buy time to gain a better understanding of global climate change and to reduce possible negative impacts attributable to human-induced climate change.[216] The major drawback of these options is their limited impact. There are many who believe that although these technologies may be sufficient in the short term, they will not be able to solve the problem in the long term as the global population and energy demand continue to increase.[217]

The fifth option, the capture and subsequent use or disposal of the CO_2 before it reaches the atmosphere, is one of several more expensive long-term technological responses. It is a controversial option, however, because it allows for the probable continued large-scale use of fossil energy resources when the international environmental community is stressing the reduction of CO_2 emissions and phasing out of

[213] *supra*, Note 15.
[214] *Ibid.*
[215] Auerbach, D.I., "Climate Change Mitigation via Ocean Disposal of Power-Plant-Generated CO_2: A Comprehensive Environmental and Political Analysis," Master's Thesis, MIT, Cambridge, MA, June 1996.
[216] Morrissey, W.A. and J.R. Justus, "Global Climate Change," CRS Issue Brief for Congress, 17 April 1998.
[217] Herzog, H., E. Drake, and E. Adams, "CO_2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Change: A White Paper Final Report," MIT Energy Laboratory, Cambridge, MA, DE-AF22-96PCO1257, January 1997.

fossil fuels. Proponents for the research and development of CO_2 sequestration argue that it is judicious to explore all potential mitigation options now so that a broad range of strategies is available in the future.[218] Opponents may either argue that the option is amoral in light of the international community's position on CO_2 emission reductions or that global warming is a myth[219] and resources should not be spent on mitigating a problem that does not exist.

Because the deep ocean is highly unsaturated in CO_2 and represents a potentially significant CO_2 sink, it is considered a prime candidate for CO_2 storage. The ocean currently contains the estimated equivalent of 140,000 billion tonnes of CO_2 (compared with annual worldwide anthropogenic emissions of about 22 billion tonnes of CO_2).[220] Storage of CO_2 in the deep ocean, therefore, is viewed by some as an acceleration of the natural process of transferring CO_2 from the atmosphere to the deep ocean.[221] The ability to dispose of large quantities of CO_2, however, involves many uncertainties in its effectiveness and the environmental impacts associated with increased seawater acidity near the injection site. Efforts to understand ocean CO_2 sequestration technologies must be undertaken to better evaluate their potential and to reduce their associated costs and risks before the technology may be considered a viable alternative.[222]

Ocean storage of CO_2 was first considered in 1977.[223] Several follow-up studies were then carried out in the late 1970s and 1980s, but it was not until the 1990s that significant research efforts were undertaken, principally by researchers in Japan, Norway and the United States.[224] If the ocean storage option is to ever be seriously considered, a combination of theoretical and experimental research efforts will be required so that informed decisions can be made. Theoretical and laboratory research

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[218] *Ibid.*
[219] Pearce, F., "Cosmic greenhouse wars," *New Scientist*, 155, 19 July 1997.
[220] *supra*, Note 217.
[221] *supra*, Note 13.
[222] *supra*, Note 217.
[223] Marchetti, C., "On geoengineering and the CO_2 problem," *Climate Change*, 1(1), 1977, pp. 59-68.
[224] *supra*, Note 217.

has been progressing, but experimental research is still in its infancy.[225]

5.2 The ocean CO_2 disposal experiment

The ocean CO_2 disposal field study consists of a series of pilot-scale tests with several key objectives:

- to better understand the physical-chemical processes affecting the transport and fate of CO_2 released as buoyant liquid droplets at water depths of about 1000 m;
- to demonstrate proof of concept;
- to develop and validate models of transport and fate, which in turn can be used to more reliably predict the environmental impact of ocean disposal of CO_2;
- to establish CO_2 deployment techniques and field monitoring methodologies that will help in future experiments.[226]

While these issues are important, the primary goal of the principal scientists is a functional experiment so that valid measurements can be taken.[227]

There are several possible mechanisms for the direct injection of CO_2 into the ocean, but the field study will examine only one. Liquid CO_2 will be pumped through a pipe from shore to the deep ocean and injected from a manifold lying on the ocean bottom so that a rising droplet plume is formed. This option is considered to need little technological development as it is relatively straitforward and minimizes the need for complex engineering. In addition, it is relatively inexpensive (The project budget is $3.8 million.[228]) and is considered to have a low-medium impact on the environment.[229]

[225] *Ibid.*

[226] Adams, E.E. and H.J. Herzog, "Scoping and Site Selection Study for an Ocean CO_2 Disposal Field Experiment." MIT Energy Laboratory, Cambridge, MA, June 1997.

[227] Herzog, H.J., Principal Research Engineer, Energy Lab, MIT, Cambridge, MA, Personal communication, May 1998. Adams, E.E., Senior Research Engineer, Department of Civil and Environmental Engineering, MIT, Cambridge, MA, Personal communication, May 1998.

[228] Herzog, H.J., Personal communication, May 1998.

[229] *supra*, Note 226.

A series of tests will be carried out over a short time period during the summer of 2000 - each test lasting several hours to a day.[230] The CO_2 will be discharged at a rate of 1 kg/s to allow for a full scale test of the nozzle design. This discharge rate will also yield a plume of sufficient size for measurements and results in acceptable costs for CO_2 use and handling.[231]

After an extensive site selection study, it was decided that the optimal location for the experiment is off the west coast of the big island of Hawaii.[232] Pipe will be laid for about 3 km west off the Natural Energy Laboratory of Hawaii Authority (NEHLA) facility at Keahole Point to a depth of 700-1000 m. NEHLA has an umbrella permit to conduct research to two miles out and has already received written approval for the CO_2 sequestration experiment under that agreement.[233] In addition to NEHLA, personnel from the Pacific International Center for High Technology Research (PICHTR) and the University of Hawaii on Oahu are also participating. The extensive engineering expertise of these organizations should be extremely useful in providing technical and scientific support for the experiment.[234]

5.3 Potential barriers to the experiment

As in the ATOC experiment, there is more than one potential controversy that could hinder the CO_2 sequestration experiment. The first level of debate is over the potential impact of the experiment itself on the marine environment. Opponents may argue that the risks associated with intentionally introducing CO_2 into coastal waters are too great and that the research should not be permitted. The second, more complicated, level of debate is over the potential long-term implications of the research. Opponents may argue that CO_2 sequestration is not in line with the international community's position on global warming mitigation and that research that supports a science that

[230] *Ibid.*
[231] *Ibid.*
[232] Kildow, J.T., Associate Professor, Ocean Policy, MIT Department of Ocean Engineering, Personal communication, 1998.
[233] *supra*, Note 211.
[234] *Ibid.*

fosters the use of fossil fuels should not be undertaken.

5.3.1 Impact on the marine environment

The first concern is the easiest for scientists to understand and debate as it involves the balancing of scientific uncertainties. There are several environmental impacts of ocean CO_2 disposal, but because the reaction of CO_2 with seawater causes a decrease in the pH, the primary effect is the acidification in the area of the release point. (Other impacts include the disturbance of the ocean bottom due to the installation of the pipe and possible problems on land involving the transport and storage of large amounts of CO_2.) The severity of the impact, however, varies substantially with the injection scenario. From modeling results, depending on the method of release, pH can be reduced to as low as about 4 at the injection point from its ambient value of 8. The results away from the injection point are even more complicated.[235] Again, the droplet plume model is expected to have a low-medium environmental impact.

The results of pH mapping from various disposal schemes are combined with the knowledge of the effects of the expected pH exposures on marine life that would be exposed to the plume to determine environmental impact. The measure of environmental impact, however, has been mortality rates. Other effects, such as reduced growth and reproduction rates, are not taken into account and could also have a serious impact on marine ecologies.[236]

The effect on the physiology of marine organisms of increased concentrations of CO_2 in seawater is dependent on both the magnitude of the increase of CO_2 as well as the tolerance of the particular organism. Information is limited on the tolerance and physiological responses of most species to an increased concentration of CO_2. The organisms that would be most affected would be those unable to avoid regions of low pH because of limited mobility (i.e., zooplankton, bacteria, benthic community). In general, the sensitivity of marine organisms is related to the compensatory

[235] *supra*, Note 212.
[236] *supra*, Note 13, pp. 9-12.

mechanisms, its energy requirements and its mode of life.[237]

Because of the uncertainties over the size of the impacted area as well as the level of harm due to an intentional injection of CO_2 into the ocean, environmental groups may feel that the risks are too great and that the project should not be allowed unless a solid monitoring system is in place and the experiment can be aborted if unintended consequences occur.

5.3.2 Potential long-term application

The CO_2 sequestration experiment is also inevitably linked to the possibility of its long-term application at larger scales. This link makes it difficult to separate the risks of the actual experiment from the risks and uncertainties of the use of CO_2 sequestration as a tool for mitigating CO_2 emissions in the debate over the value of the experiment. Many environmentalists think that the primary effort should be put into the capping and reduction of greenhouse gas emissions and not mechanisms for allowing continuing or increased emissions. This more complicated level of debate may seem irrelevant to the scientists conducting the experiment, but it is an attitude that prevails.[238]

There is also scientific uncertainty in the long-term application of CO_2 ocean sequestration related to the efficiency of the mechanism. The storage capacity of the ocean for CO_2 and the residence time of the injected CO_2 are both unknown quantities and are presumed to depend strongly on the method and location of injection.[239]

The potential for a long-term application also ties the research to industry although industry is not supporting the research currently because of the high costs associated with large-scale CO_2 sequestration.[240] Many environmental groups do not trust any industry-related science because of the record of one-sided presentations of the data. This mistrust may also have to be addressed.

In addition, in 1972 the United Nations Conference on the Human Environment

[237] *supra*, Note 13, pp. 17-19.
[238] *supra*, Note 232.
[239] *supra*, Note 212.
[240] *supra*, Note 228.

articulated several principles that have provided the basis for conventions that have subsequently been developed to conserve the planet's resources. One of these principles emphasized that measures which transfer damage from one biome to another must be avoided. In the short term CO_2 sequestration in the ocean obviously violates this principle as it takes CO_2 that would pollute the atmosphere and deposits it directly into the deep ocean. Scientists involved with the experiment claim that ocean sequestration merely accelerates a natural process whereby the CO_2 would ultimately end up in the ocean as CO_2 concentrations in the ocean and atmosphere will equilibrate in the long-term. Thus, the issue becomes clouded.

5.4 Public outreach

The public outreach component of the ocean CO_2 disposal field study is just beginning. Because the goal is to educate and involve the public in a meaningful dialogue, a gradual outreach strategy is being developed as opposed to a flashy public relations campaign. The primary function that has been carried out to date has been information gathering in Hawaii so that the scientists can be prepared to establish a sound program. The key issues that have been investigated are:

- the dynamics of local politics,
- the names of key stakeholders and their perceptions of marine science,
- potential supporters as well as adversaries, and
- previous or current local environmental issues.[241]

Hawaii holds a very complex web of environmental groups, government-based interests, and research institutions. Some of these stakeholders have been identified and will be approached in the near future to gage their opinions of the experiment. Previous environmental issues that have surfaced in Hawaii, including ATOC, also

[241]Kildow, J.T., Progress Report in Final Report to PICHTR, 7 April 1998.

provide insight into the local dynamics that may provide support or opposition to the CO_2 sequestration experiment.

Chapter 6

Policy Protocols for Marine Scientists

The previous chapters have described the current state of affairs for oceanography and marine science and have provided specific examples of relevant research in order to establish the foundation for the policy protocols described in this chapter, the ultimate goal of this thesis. Through the analysis of the co-evolution of marine science and policy, the recent transition to a more democratic science becomes apparent and the unease of marine scientists in this new era even more so. With this new democracy comes an increased public scrutiny, for which most scientists are unprepared.

The policy protocols described below are designed to assist marine scientists considering experimentation in the oceans in maximizing the potential benefits of intense public scrutiny and minimizing the possible costs. They are not a recipe for success, but rather a set of guidelines to help scientists constructively utilize the input of the public while still maintaining control over the direction of their research. Through the utilization of the new set of policy protocols, scientists should be able to invite public scrutiny and incorporate public participation while still maintaining appropriate scientific methods and standards.

Because the circumstances surrounding each research project will be unique, the protocols have been designed to be deliberately broad to capture as much of the oceanographic research spectrum as possible. The protocols are then applied to the ocean CO_2 disposal field experiment described in Chapter 5 in order to provide a concrete example of their utility.

While a complete description of the policy protocols is given below, a condensed version illustrates the basic approach to public involvement in marine scientific experimentation:

- Establish a broad support base within the scientific community.
- Identify stakeholders and engage in appropriate public outreach.
- Expect inefficiencies and plan accordingly.
- Conduct research in a transparent fashion throughout all of the phases of research - planning, implementation, monitoring, and distribution of results.
- Maintain management flexibility capable of working with change and the relevant interest groups.

These protocols give scientists a tool to use when participating in the democratic process so they do not become its victims. They are now elaborated upon and discussed within the context of the CO_2 ocean sequestration experiment.

6.1 Establish a broad support base within the scientific community

Scientists should always expect detractors, even from within the scientific community, but it is important to establish a strong network of support for potentially controversial research. Establishing this support base does not mean that the scientists must capitulate to others' opinions so that a consensus may be reached on a highly controversial issue, but that they should seek input and support from areas they might not have previously considered.

Scientifically broad support

When establishing the program within the scientific community, it is important to seek input and support from within the narrow field of research with which the project is most closely associated, but it is also wise to seek relevant outside support. A side benefit of this exchange is that the experiment may become better science. By keeping an open mind, scientists can learn more about their own problem by viewing it from another direction.

ATOC scientists could have benefited from discussing their research with marine biologists before they were forced to do so. Earlier discussions would have ensured a better exchange of information and may have prevented many of the misunderstandings that occurred. In addition, a better marine mammal component of the research might have existed from the start without the reduction of the acoustic tomography component.

Because the ocean CO_2 disposal field experiment has been established within the context of the problem of large-scale CO_2 sequestration, the scientists have benefited from exposure to the various faces of the problem from the very beginning. They would be wise to continue discussions with the chemical and biological oceanographers as their research progresses.

A broad support base may also be enhanced by accurately identifying and stressing the importance of the science and the value of the data to be collected. The DSDP and ODP were able to promote their research based on the importance of their science alone. ATOC, however, missed the opportunity to present itself as a valuable source of an enormous amount of novel information on many oceanographic properties and therefore did not emphasize the importance of the science as it could have. The CO_2 experiment needs to follow the example of the deep-sea drilling research and stress the scientific benefits that will come of the research as opposed to just the potential applied benefits if ocean sequestration should become a viable CO_2 mitigation option.

Geographically broad support

In establishing a support base, it is also prudent to consider the location of the experiment. Given local interests, local scientists may provide a certain level of accountability and trustworthiness that is not present in a group of "outsiders." Care must be taken, however, to ensure that the objectives of the cooperating institutions are reconciled before formally proceeding. As shown in the Project Mohole experiment, differences in opinion at the highest levels can help to destroy projects. The earlier the various objectives/agendas can be identified, the earlier a consensus can be worked out and a united front presented.

Being perceived as "outsiders" could seriously impede the CO_2 sequestration researchers as it did the ATOC scientists in Hawaii. Fortunately, there are several scientific institutions on the islands that are participating in the project. The principal scientists of the ocean CO_2 disposal experiment, NELHA, PICHTR, and the University of Hawaii may be able to work together, but a tightly coordinated effort must be undertaken. While the University of Hawaii and the backgrounds of the principal scientists are primarily research-oriented, NELHA and PICHTR are more concerned with the economic development of Hawaii. These objectives are not necessarily mutually exclusive, but they will require consideration in the decision-making process.

For issues involving international concerns, an international foundation should also be established to provide credibility to the project. The collaboration between the U.S., Japanese, and Norwegian governments in the CO_2 sequestration experiment complicates matters with regard to funding issues and differences of government agendas, but it establishes an international level of accountability and trustworthiness within the international community. Again, the differences in objectives must be identified early and reconciled if the project is to have an obtainable goal. Fortunately, the CO_2 scientists are well aware of this potential hurdle and are currently working toward a suitable arrangement.

6.2 Identify stakeholders and engage in appropriate public outreach

All possible stakeholders must be identified and a dialogue must be established with each of them so that potential problems may be recognized and resolved before they magnify. While there will always be fringe elements, not every opponent should be viewed as such. Every attempt must be made to bring the relevant stakeholders to the table so that a balanced view of the problem is presented. If a decision is made without all sides present, the decision will not be respected as valid, and strong objections may be brought up at a later, more inconvenient time.

Once the stakeholders have been identified, it is important to engage in a gradual public outreach early in the planning stages instead of bombarding them with a flashy public relations campaign once all of the details have been set. As seen with ATOC, high visibility without an informed public can lead to the rapid dissemination of incomplete and inaccurate information. The difference between public outreach and public relations becomes apparent when their objectives are compared. Public outreach attempts to *educate* the public by providing accurate and complete information while public relations attempts to *persuade* the public by providing only the information that will support the position of those that are supplying the information. If the process is to be truly democratic, all of the information must be made available and public relations is not an appropriate mechanism for engaging the public.

The ocean CO_2 disposal field experiment involves many stakeholders, including environmental groups, fishermen, recreational interests, commercial ventures established at NELHA, political groups, and local scientific organizations. As discussed in Chapter 5, representatives from these groups have been identified and discussions will begin to take place in the near future. These discussions should be low-key and should attempt to provide as much information as possible. The scientists should be willing to listen to the concerns of the stakeholders at this time without immediately dismissing them. The initial conversations will be extremely educational for all sides if the dialogue is kept open and accusations are left at the door.

6.3 Expect inefficiencies and plan accordingly

As is the case with international cooperation, a democratic cooperation will be extremely inefficient. Many scientists who are involved in international collaborations recognize the value of such cooperation and see the tradeoff in efficiency as worthwhile.[242] This is not yet the case for the democratic process. It must be understood that the democratic process is not efficient, but that there are benefits to be gained from entering into a democratic partnership with the public. Once this is recognized, the planning process can begin to accommodate the new inefficiencies and not become overwhelmed by irrelevant issues.

The arguments for the democratization of science and science policy are many: (i) All citizens support science through their tax dollars and experience the profound consequences of science, both good and bad. (ii) In a democracy, those who experience the consequences of an activity and those who pay for it ordinarily expect a voice in decisions. (iii) Scientific leaders have no monopoly on expertise, nor do they have a privileged ethical standpoint, for evaluating the social consequences of science and of science policies. (iv) Non-scientists already do contribute to science and science policy. (v) Elite-only approaches are antithetical to the open, vigorous, and creative public debate on which democracy, policy-making, and science all thrive. (vi) There is a danger that public support for science will erode if other perspectives are excluded.[243] Promoting the democratization of science can help establish U.S. science policies that are more socially responsive and responsible, more widely supported, and more consonant with the tradition of openness in science and a healthy democracy.[244]

The CO_2 sequestration scientists have shown an awareness of the increased public scrutiny that they may face and are taking steps to solicit the public's input. Because it is a long process they have begun to consider their options during the initial planning stages of the experiment. Care must be taken, however, to see that the public outreach is actually incorporated into the experiment preparations and not left on a

[242] *supra*, Notes 77 and 228.
[243] Sclove, R.E., "Better Approaches to Science Policy," *Science*, 279, 27 February 1998, p. 1283.
[244] *Ibid.*

back burner until it is too late.

6.4 Conduct research in a transparent fashion

Transparency is the key to establishing public trust. If the public thinks that relevant information was withheld, decisions will not be trusted – even if they are correct. The next several issues deal with the transparency of the research throughout the entire project. While this is most important during the planning stages when the public trust is being established, it cannot be ignored once the experiment starts. Public outreach is a long-term commitment and needs to be treated as such.

Because the CO_2 experiment has not yet begun, each of the following steps applies broadly to the project. As the experiment develops, a picture of the action appropriate for the CO_2 experiment will become better defined. For example, uncertainties still exist as to the necessary permits.[245]

Obtain appropriate permits and authorization

Applicable legislation and regulation must be identified and complied with. This should also be done as early as possible as permitting agencies must also deal with the public and the process can take more time than expected.

Present what is known and what is not known

An unambiguous presentation of the information and level of risk involved must be made to the public before the experiment begins so that all parties are aware of the goals and uncertainties of the project. A rational opinion may be made only if all of the data is made available.

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[245] *supra*, Note 232.

Carry out the research as openly as possible

Document everything and insure high quality. The public trust needs to be maintained if the scientists are to produce data that will be considered valuable in the end.

Establish a reliable monitoring system

In any experiment that involves risk to the environment, a reliable monitoring process is essential. The process must be considered open and neutral to all involved parties or the entire procedure is meaningless. The oversight of the experiment is necessary to validate the public's concerns over potential risks and to assure them that the risks are being mitigated. Assurances must also be made that the experiment will be aborted if unintended consequences occur.

Distribute the results to the public

Once the experiment has been completed, the results must be translated and shared with the public as well as the scientific community. Again, these results must be considered unbiased by all parties if the integrity of the project is to hold.

Seek feedback on the process

After the experiment has been formally completed and the results have been distributed, the scientists should seek feedback from the public. This is especially important if there is the potential for future research. If so, the feedback can serve as an iterative step in the process toward the next experiment.

6.5 Maintain management flexibility capable of working with change and the relevant interest groups

As was seen in the deep-sea drilling research, a strong, flexible leadership can sustain a project. The managers of the project must not only be able to have a solid foundation in the science of the experiment, but they must also be representatives for their research to the public and relevant government agencies.

Strong and adept project representation

The representatives of the project should be able to clearly state their position and be willing to listen to the concerns of the public. Scientists that cannot cope with public debate should not be put forward as representatives of the project.

Separate the layers of debate

It is usually the case that in policy/value decisions involving scientific uncertainties, the scientific problem is much less important than the policy problem.[246] It is important then to ensure that the agencies responsible for deciding whether to allow a certain project to exist separate the two levels of debate: one scientific, the other political.

The CO_2 sequestration project is currently controversial at the political, value-driven level and less so at the scientific level. The principal scientists need to ensure that their experiment is judged at the scientific level by permitting authorities. If the experiment becomes embroiled in a dispute over whether the information should even be sought, the scientists will have lost control over their experiment.

[246] Casper, B. "Technology, Policy, and Democracy," Science, 194, 1 October 1976, pp. 29-35.

Flexibility in project goals - for long-term projects

It should be understood that the knowledge base changes over time, as do the political and funding climates. If a project is to continue over long periods of time ($>$ 5years) then the management of the project must be aware of these changes and adjust the project goals to accommodate them. This is not to say that the research must always follow the latest scientific fads, but that it must not continue operating in a specific manner just because that is the way it has always been done.

Appendix A

Legislation relevant to marine scientific experimentation

Year	Common name of legislation (United States Code source)	Application Requirements
1969	National Environmental Policy Act (42 U.S.C. §4321-4370)	general environment Environmental Impact Statement
1972	Marine Protection, Research and Sanctuaries Act (33 U.S.C. §1441-1445)	marine research (Title III) 'consistent' science pollution (Title II) permit
1972	Amendments to the Federal Water Pollution Prevention and Control Act (33 U.S.C. §1251-1387)	pollution permit
1972	Marine Mammal Protection Act (16 U.S.C. §1361-1421)	species protection scientific permit

Year	Common name of legislation (United States Code source)	Application Requirements
1972	Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter	pollution (ship-based) permit
1973	Endangered Species Act (16 U.S.C. §1531-1544)	species protection scientific permit
1982	United Nations Convention on the Law of the Sea	marine research (Part XIII) pollution (Part XII) 'consistent' science

Note that 'consistent' science is defined as research that is consistent with the other provisions of the legislation.

Appendix B

Acronyms and abbreviations used

AMSOC	American Miscellaneous Society
ATOC	Acoustic Thermometry of Ocean Climate
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DSDP	Deep Sea Drilling Project
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FWS	Fish and Wildlife Service
HIFT	Heard Island Feasibility Test
IODP	Integrated Ocean Drilling Program
JOI	Joint Oceanographic Institutions, Inc.
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
LDC	London Dumping Convention
MIT	Massachusetts Institute of Technology
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MMRP	Marine Mammal Research Program
MPRSA	Marine Protection, Resources, and Sanctuaries Act
NEHLA	Natural Energy Laboratory of Hawaii Authority
NEPA	National Environmental Policy Act

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
ODP	Ocean Drilling Program
ONR	Office of Naval Research
PICHTR	Pacific International Center for High Technology Research
SERDP	Strategic Environmental Research and Development Program
SIO	Scripps Institution of Oceanography
SOFAR	SOund Fixing And Ranging
TAMU	Texas A & M University
UNCLOS	United Nations Convention on the Law of the Sea
WHOI	Woods Hole Oceanographic Institution

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