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Reported are the papers presented at the New England Conference on Ocean Science Education. The purpose of the conference was to bring together prominent oceanographers and New England educators at the primary and secondary level to discuss current progress in oceanographic research and to relate this progress to the needs of schools for materials and methods which are interesting and useful in motivating and informing students. Some of the topics presented were the teaching of oceanography, oceans and national welfare, the outlook for oceanography in the future, current oceanographic research in various disciplines, manpower needs, instructional equipment and materials, the development of marine science information centers, teacher education, and the training of oceanographers. Also included are the proceedings of panel discussions and recommendations. (DS)

Proceedings of the New England Conference on Ocean Science Education

May 20-21, 1966

Proceedings
of the
New England Conference
on
Ocean Science Education

Woods Hole, Massachusetts
May 20 & 21, 1966

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Preface

The papers collected in this report were presented at the New England Conference on Ocean Science Education at Woods Hole, Massachusetts, on May 20 & 21, 1966.

The Conference was jointly sponsored by the Woods Hole Oceanographic Institution, the Massachusetts Department of Education and the Falmouth (Massachusetts) Public Schools. The purpose of the Conference was to bring together prominent oceanographers and New England educators at the primary and secondary school level to discuss current progress in oceanographic research, and to relate this to the needs of the schools for materials and methods which are interesting and useful in motivating and informing students.

The Link Foundation provided financial support which made the Conference possible; that support is gratefully acknowledged.

The editors wish to apologize for the long delay in publishing these proceedings. A series of unforeseen and unfortunate events since the Conference has thwarted our every prior attempt to publish them.

Frederick E. Mangelsdorf
Clarence B. Lindquist
John W. Packard

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Overview of the Conference

John W. Packard

Dr. Kiernan has asked me to give you an overview of what we are planning to do at the Conference. This will be brief because we have some very knowledgeable people to follow me and this, of course, is why you have come. I would like to give you a summary of the genesis of this meeting, the people and the organizations who have made it possible, something about the planned agenda, and to indicate to you what we hope to accomplish today and tomorrow. This goes back about two years to the spring of 1964 when Dr. Kiernan was at a meeting in Los Angeles which was sponsored by NASA and the U.S. Office of Education and was devoted to the subject of aerospace. At that time, Dr. Lindquist, whom you will hear from later in the program, Dr. Sorenson, who will be at the meeting tonight with Miss Link representing the Link Foundation, and Dr. Kiernan pointed out the parallel between the Space program and what is happening in the oceans. Just as there are many interesting and important things happening in aerospace, so are exciting things happening in hydrospace. They are both vital to our national defense, they are both rich in economic possibilities, and of particular interest to us in education is the fact that this, for our young people today, is a new frontier full of excitement and promise. This is their frontier. These are the things that motivate them, that interest them, and Dr. Kiernan and the others felt that there was an obligation here to explore the possibilities of passing this new knowledge and this vital excitement on to our schools. Dr. Kiernan suggested that we should have a meeting to discuss this and explore its possibilities. Last year the lead time was too short and it was agreed to put it off until this year. We contacted Dr. Fye and Dr. Ketchum here at Woods Hole, and we were tremendously gratified at the interest they showed. They offered us the assistance of their staff, and these very attractive surroundings to carry out this meeting. To make a long story short, here we are.

I might say that some funding was obtained; we approached the Link Foundation for this. Some of you may remember the exciting days of early aviation when the name Link was synonymous with the Link Trainer. Mr. Edwin Link went on to become a pioneer in the second generation of simulators and trainers as they applied to much more exciting things than the old-fashioned Link Trainer. Subsequently, he became interested in the oceans and in looking for sunken treasure. Since then, he has devoted a tremendous amount of his time to looking for all kinds of treasures beneath the ocean surface, including the scientific information which we think is more valuable than gold coins. We are happy that the Link Foundation is supporting this meeting, and I hope Miss Link will be with us tonight, weather permitting.

Thus the conference was organized. Dr. Fye designated Mr. Mangelsdorf, his Administrative Aide who has been of tremendous help as a member of the organizing committee, to work out the details and make the facilities available to us. Another member of the group which planned this conference was Dr. Lindquist of the U.S. Office of Education who has been loaned to the State of Massachusetts as a consultant. He represents the U. S. Office of Education, of course, but he also is a Massachusetts consultant during this year. As to the agenda, I think you probably will have noticed that the first part of the program will be developed by the professional oceanographers and scientists. Our hope is that we will be helped to update our knowledge of ocean science. Tremendous things have been happening in this area. You know about some of them, of course, but they resemble an iceberg; nine-tenths of this tremendous development is going on beneath the surface. Speaking of being beneath the surface, you are all going to have a chance to see the facilities here. You will note on your program that there are arrangements to see ATLANTIS II and to see ALVIN. I was amazed to find that ALVIN, whose inventor, Allan Vine, is here with us today, isn't a little sausage at all. Stripped of its exterior covering, it is essentially a big ball and this explains a lot of things to me. I think you are going to enjoy this opportunity very much.

The second part of the program deals with the interest of the Federal Government in this conference. Our program lists these people, and I am sure you are going to enjoy hearing of the programs and plans at the Federal level at this evening's meeting.

Tomorrow will be devoted to ocean science education in our schools. You will have reports from very knowledgeable people who have already pioneered in this field in developing curricula, experiments, and programs in the schools, and following that we will have six concurrent panels. These panels, I hope, will be the culmination of the meetings, at which time we shall put together what we know and what we think should be done. I hope that some very specific recommendations will come out of these meetings.

A number of projects have been funded recently by the Elementary and Secondary Education Act under Title III. They range from projects on marine science in Florida, up the east coast to Massachusetts and to Maine. The people who are connected with these projects will report to the panels what their plans and their ideas are. Following this, the chairmen of the six concurrent panels will report to you in general session here. Dr. Thistle, Director of the Bureau of Elementary and Secondary Education in Massachusetts, will summarize what we have heard here. Dr. Lindquist, Mr. Mangelsdorf and I will edit the deliberations and papers developed here in order to print a set of "proceedings". We have hopes that these will be published and distributed nationally and it may well be that some of the ideas, some of the recommendations that are made here will lead to further developments. I come from Pilgrim Plymouth and I thought I would close by a quotation from the first governor, Governor Bradford, who said this:

> "As one small candle may light a thousand, so the light here kindled has shone unto many, yea, in some sort, to our whole nation."

Perhaps we can do as well.

CHAPTER I

THE OCEANS AND THE NATIONAL WELFARE

Welcoming Address

Dr. Paul M. Fye

Dr. Sanders, Ladies and Gentlemen: It is a distinct pleasure to welcome all of you to Woods Hole today. We are delighted that you are having this conference at the Woods Hole Oceanographic Institution, and I hope the setting here in the midst of our research activities will help insure its success.

Our scientists have a primary role of conducting basic research in oceanic phenomena and the living creatures in the oceans, and we are probably better known for these research programs than for our educational activities. Our particular bent and interest in education has been much more at the doctorate and post-doctorate levels than at the secondary school level. This comes about quite naturally because of the interdisciplinary nature of the study of the oceans. It is important that scientists delving into the secrets of the oceans not only have a background in sciences that is extensive in one branch, but also broad in the interrelationships between various areas of science.

It is important to us, and I hope to you, that this meeting is in Woods Hole. In interpreting marine science to young people, one of the most challenging and exciting facets is the story of what is being done in trying to understand the oceans. I do not pretend to be an expert in your field of teaching young people, nor do I pretend in these brief welcoming remarks to attempt to embrace the sciences of the ocean. But as a parent, interested citizen and ex-teacher, I am much concerned with the problem of how to communicate to young people the excitement of the intellectual activities going on in the world today. I believe that the story of the oceans is one of the doors that we can open to show them that these intellectual activities are exciting, challenging and fun.

As all of you know, more than 70% of the earth's surface is covered by water. The oceans contain vast amounts of resources--minerals suspended in the water, minerals in the bottom, animal life of all sizes, and so on. The oceans also control our weather to a large extent, and they provide a means of transportation to our friends and a barrier to those not so friendly.

The oceans are indeed important to us, and we must learn more about them. Those of us actively engaged in oceanic research find it challenging and, yes, fun too. We hope that during your short visit here we shall be able to impart some of this enthusiasm to you, and that you will find ways of imparting it to your students.

We recently had an Open House for our many friends here in Woods Hole and Falmouth, and many of the displays are still available. All of you are welcome to visit our laboartories and to see these displays. Both of our newest research vessels--ATLANTIS II and ALVIN--are here, and you are welcome to visit them also.

I hope that you enjoy yourselves while you are here and that your conference is a successful one.

The Teaching of Ocean Science in Our Elementary and Secondary Schools Is in the National Interest

Dr. Owen B. Kiernan

We of the Commonwealth's Department of Education are indeed happy to be one of the hosts for this conference, the first large-scale meeting ever held on this vitally important subject. As you are aware, Massachusetts is a State of many firsts, including the establishment of the first public school in the United States. We desire to continue this rich tradition of leadership and recognize with citizens everywhere the vital contributions of our schools and colleges to the national welfare and security. Toward this end, the Massachusetts Department of Education is currently conducting a project on space science education for the National Aeronautics and Space Administration, as well as a computer assisted instruction project in mathematics with financial support from the U.S. Office of Education. We recognize that oceanography is, like space science and computer technology, a rapidly growing field which cannot continue to be ignored in our elementary and secondary schools. Therefore, we are pleased to be one of the organizers and hosts of this New England Conference on Ocean Science Education.

We all remember October 4, 1957. On that day the Russians launched Sputnik I, the earth's first artificial satellite. Immediately many critics blamed American education for our failure for not being first in space. One positive dividend resulting from this criticism was greater interest and increased financial support of American education at all levels. The Federal Government assumed a new role, and massive Federal programs, from the National Defense Education Act of 1958, to the more recent Elementary and Secondary Education Act of 1965 and Higher Education Act of 1965, have done much to improve the quality of our educational system.

It took Sputnik I and the Space Age to stir Americans into action about their schools. Now inner space--our oceans--is coming to be regarded as important, if not more important to our national welfare than outer space. Congressman Keith recently visited the Soviet Union and he will tell you very shortly about what the Russians are doing in oceanography. Dr. Lindquist, my conference assistant, visited the U.S.S.R. in 1959 and reported in an Office of Education publication the great effort the Russians are putting into education. I mention Sputnik to remind all of us that we must not fall behind in the conquest of inner space. This is one reason why I believe that we should do all that we can that is appropriate in the way of education. Not only do we need adequate numbers of fully trained and competent oceanographers and oceanographic engineers and technicians, but we need perhaps equally as much an informed, enlightened citizenry which understands the importance and full potential of the oceans for defense, for food, for water, and raw materials.

It seems natural that this first ocean science education conference should be held in New England. From the days the Pilgrims first stepped ashore at Plymouth, the lives and destinies of a great portion of the people of New England have been inextricably bound to the oceans--through ocean commerce, through shipbuilding industries, through fishing, and through recreational activities.

In organizing this conference, it has been our objective to bring together experts, both scientists and educators, local, state and national, to assess the current status of the teaching of ocean science in the elementary and secondary schools and to determine what new directions are needed. I am confident that this conference will produce recommendations which will be helpful, not only to educators in the New England region, but to the rest of the country as well.

Outlook on Oceanography

Representative Hastings Keith

As I speak to you tonight, congressional efforts for major legislation in oceanography are gaining momentum. My most exciting work in Congress lately has been in the Merchant Marine and Fisheries Committee, particularly the Oceanography Subcommittee. I originally sought assignment to this committee in order to be of greater service to my district--a district which has a long maritime tradition. Fishing, as you all know, is a principal industry of Southeastern Massachusetts. Moreover, the area has a remarkable concentration of oceanographic talent, centered, of course, at Woods Hole.

However, as I began to learn more about this field of oceanography and, as I began to apply what I was learning in Congress, I realized that this was a rare opportunity for creative legislation. The field is young, and much broad thinking and planning still needs to be done.

Two pieces of legislation pending before Congress right now will, if enacted, change the entire course of oceanography in this nation. One bill, which has been passed in different forms by the House and the Senate and is at this moment in conference, sets up a National Council of Marine Resources made up of Cabinet Members and perhaps as well a Commission composed of members of industry, the academic world and government. They would have a broad mandate to recommend sweeping changes in our national oceanographic program.

The objective would be to take a long, hard look at all our marine science activities in order to recommend a long-range, comprehensive plan. An imporved national organization for our program would be one of the highest priorities. The possible solutions range from establishing a new Cabinet-level department to merely improving communication and cooperation among agencies involved in the ocean sciences. Old programs would be re-evaluated and new priorities set. The result would be a quickening of the pace and efficiency of our entire effort.

Other problems that would be addressed are the roles of industry, the relative importance of technology and basic science and the appropriate goals for oceanographic education. It is my hope that all of you, as educators, will follow carefully the outcome of this legislation. If it passes this year,[1] the Council and the Commission will be making recommendations to Congress in about two years. I hope that all of you will make your voices heard.

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[1] Editorial note: The bill was passed by Congress and signed by President Johnson into law (P.L. 89-454)

The other bill now pending is of more immediate concern to you because it provides a solid future for ocean science education and promises to inject real vitality into the field. The bill is known as the "Sea Grant College" bill because it would establish a system analogous to the Land Grant College. Hopefully, passage of the bill would be followed by the same burst of activity and rapid development in oceanography that occurred in agriculture as a result of the Land Grant Colleges Act about a hundred years ago.

The bill provides for grants to colleges or other institutions to initiate or support programs of education and research in the marine sciences. Additionally, it provides for practical instruction and demonstration programs for those already employed in marine work. The emphasis at first would be on the practical and engineering side of oceanography since this is at present the least effective part of our program. Interest in this imaginative idea is high. And I think that many Congressmen share with me the view that education will provide the only truly solid foundation for all our future oceanographic efforts. Congress can plan all the expansion it wishes and appropriate vast sums, but we will still not progress without well-trained personnel to carry out the job. There is no question that the quality of the education we provide today in the ocean sciences will determine the shape of our oceanographic program for years to come.

Moreover, it is of the utmost importance that we act now to provide superior education to our future oceanographers and that we develop a truly effective national program. Whether we like it or not, we are in the race for inner space, the race to control the seas.

It is obvious to us that the Soviets are aiming to achieve total supremacy at sea. They consider oceanography to be an essential part of their effort, assigning it a high priority in their total program, which also includes a rapid buildup of their merchant and fishing fleets as well as their navy. We appear to be ahead of them in basic ocean science as well as in several specific areas such as deep submergence and instrumentation. However, we are lagging in applied research, particularly in regard to fisheries. Our fragmented oceanographic program now spreads thinly over 18 or 20 different government bureaus, does not appear to be as efficient as the more centralized and carefully directed program of the Russians. Finally, it is of major concern to us to learn that the Soviets have 8,000 or 9,000 people employed in the marine sciences, including 1,500 professional oceanographers and 2,000 in supporting personnel.

We in Congress can lay the groundwork to remedy these situations and, hopefully, we can count on you as teachers and oceanographers to carry the work ahead. The future of oceanography will depend on our joint efforts.

Looking Forward in Oceanography -- A Plea for Courage Tempered with Discretion

Robert B. Abel

Miss Link, Congressman Keith, Mr. Chairman, distinguished guests, ladies, and gentlemen: Mr. Chairman, I share your remarks concerning our wives, because you see, oceanographers are often reminded of the similarity between their wives and the medium in which they work. Both are always beautiful, sometimes serene, sometimes not so, and my friends, there is never any doubt about who is boss! To reiterate the Commissioner's remarks: my pleasure at being here tonight is doubled, because not only is it always a privilege for an oceanographer to spread a little more of Father Neptune's doctrine, but, it was just about 18½ years ago, very close to this spot, that Dr. Bostwick Ketchum, now Associate Director of the Woods Hole Oceanographic Institution, uttered those two very fateful and critical words which changed my whole life; "You're hired!" And only the good Dr. Ketchum and the Lord above know how many times those words came back to haunt him in the years following.

In those days nobody knew what an oceanographer was. If you wanted to read the developments in journals you could perhaps go to the Journal of the American Geophysical Union. Today, a study that has been performed for us by the National Oceanographic Data Center lists some 49 journals, magazines and periodicals directly bearing on oceanography or on a closely allied subject.

Returning now to the point of my entry into the field--at that time there was in the United States, one industrial firm making the tools of oceanography. Today one list some 2,000 fims interested in oceanography, and there are now over 20 firms in the United States capable of setting forth their own fleets, manned by extremely competent staffs, stemming from well-equipped laboratories. At least 100 firms can currently mount respectable programs in applied oceanography. Our listing of institutions offering curricula in oceanography, which you possibly saw on the board outside the meeting hall, now contains about 50 such institutions. This year we received requests to include curricula in oceanography from four institutions in Arizona alone. We have received a brochure from a college offering a master's degree in oceanography without one person in the department who had ever had a single course in oceanography. Their program was coordinated by a person who had received a bachelor's degree in mathematics some 30 years previously, from a non-accredited school. That bothered us just a little bit!

A decade ago oceanographers could join either the American Society of Limnology and Oceanography or the American Geophysical Union; today the poor oceanographer confronts a matrix. Now, if you want to fill this matrix plot, in the first column, the standard words "American", "National", "United", etc., in the second column, you must write "Oceanography", "Marine Science", "Ocean Technology", etc.; and in the third column the usual "Society", "Association", "Group" etc. No matter how you solve that matrix I can almost guarantee you the Existence of a society to match that name!

Thus it is a little bit bothersome for the poor fellow who must join something. We estimate that there are going to be between 200 and 300 meetings on oceanography this year, and nearly every engineering society in the Unived States anticipates at least one session on oceanography. The American Institute for Astronautics and Aeronautics is going to have at least six meetings in different parts of the country on oceanography. The Third Space Science Conference which was held in Florida a few months ago, had 10 sessions. One of these, oceanography, outdrew all the sessions on space.

From all of this we can draw 3 conclusions: First, we do have indeed plenty of public relations but they are in quantity and not of quality. Judging from the mail we receive, the American public seems to conceive of oceanography as a skin divers' heaven or the establishment of a few machines sitting on the ocean bottom processing billions of gallons of water through their bowels by the hour and spitting gold out the exhaust. This is not going to happen so perhaps there is room for some rein on the band wagon in the sense of sober appraisal and in the sense of education. Second, we find to our immense satisfaction that all sectors of this nation are thoroughly aroused and excited by the prospect of entering this grand new field. Third, industrial growth necessitates a new outlook, especially when firms can perceive over the horizon the first faint glimmerings of peace (or call it what you will) and a gradually diminishing need for heavy industry in defense and in space! This might be a premature outlook, but it is time for industry's entrance.

The Federal agencies have maintained leadership by allying their missions of public service with those of the oceanographers. The universities certainly have borne the brunt of promoting oceanography for a long time. But of them all, there is no more sea-minded organization than the Congress of the United States. Believe me, it is rather a thrill to be able, now and then, to work for these people, who although generalists, are perceptive generalists, alert generalists, and enthusiastic generalists when it comes to looking at what the oceans are someday going to do for us. Now, it remains only to educate the taxpaying public itself as to what is in the seas for mankind.

Briefly, these benefits include (in addition to Defense) recovery of living and mineral resources, health, pollution control, recreation, shore protection, fresh water extraction, weather forecasting, and transportation. We must, however, think of these benefits in balanced terms rather than going completely overboard for ocean exploitation. Let's consider fisheries development, for instance. It's important to realize that only 1% of all the world's food intake comes from the sea (although it encompasses 12% of the world's protein intake). Further, as Congressman Keith says, there are many have-not nations whose wants would be partially filled by proper exploitation of the sea's resources. But <u>Americans don't like fish</u> and that is the other side of the balance.

A similar service of balance is needed with respect to mineral recovery. According to some enthusiasts, as technology improves it is going to be cheaper to extract minerals from the ocean and as we deplete land resources it is going to become more expensive to extract minerals from the land; at that point in time where the two curves cross, it will be economically feasible to extract any given component from beneath the sea. Of course, this is an interesting example of how to lie with statistics because we have probed only the very thinnest crust of the ocean and there is plenty more down there. Clearly any development of ocean technology will be accompanied by a concomitant development of land technology so that again we have to consider the balance to understand the need for proper education.

We discuss recreation and the effect of the oceans on recreation, and we are all startled, really astounded, to realize how much time Americans do spend in water recreation.

We find that 7½ million Americans spent about $2½ billion in 1963 on pleasure craft alone and in that year 36 million Americans went on the water more than once; since then, that figure has risen by at least 20%. Ten years ago, no one had ever heard of SCUBA; now we estimate that if every SCUBA diver in the United States hit the water simultaneously, the resultant rise in tide would flood the building in which you are now sitting.

We talk about pollution control (or waste abatement depending on which side of the fence you happen to be) and I'm reminded of one of the first projects handed us when I was here at Woods Hole, that of solving a pollution problem in the Raritan Bay area. We went down there in 1948 and found that the little wooden disc which is lowered to indicate water clarity almost disappeared before it hit the water! The previous survey made by the Rutgers University Sanitation Laboratory in 1928 had predicted that by 1930, 11 million gallons of effluent per day would traverse the Raritan River system, that by 1940 the figure would be 14 million gallons per day and that by 1950 it would be 22 million gallons per day. Our 1948 survey did not find 22 million gallons per day; we found 130 million gallons per day!

So we know now that the ocean is not an inexhaustable garbage can as the public has been led to believe. Again--there is the need for education, and really the only meaningful way in which we will project an honest assessment of oceanography and its possibilities is through the schools, particularly the secondary schools where the children are learning at the grass roots level. This is my particular motivation in coming to you this weekend and speaking to you in this context.

CHAPTER II

OCEANOGRAPHY TODAY

Current Oceanographic Research in the Biological Sciences

Dr. Howard L. Sanders

My knowledge of oceanography is truly very limited and this is a normal situation for oceanographers, as the areas of ignorance about the oceans overwhelmingly dominate the areas of knowledge.

Rather than trying to cover the many facets of fundamental investigations being carried out by biological oceanographers at this institution--which include such basic studies as the primary production of the microscopic plants that are the ultimate source of all food in the sea, the determination of the nutrient chemistry that largely controls the amount of primary production, organic aggregations in the sea, migration patterns in micro-organisms and migrations of larger fish--I will confine myself to an area that I know more about. This is the study of bottom communities, and more specifically, the bottom fauna living at the great depths of the sea.

Let's think of this environment for a moment. The ocean floor under 2000 meters depth is the largest single common environment on the surface of the earth. Yet, it's amazing how little we know about it. Its key characteristics are stability and constancy. It's an area where light is absent, where the temperatures are low and constant. The salinities are also constant, and even the sediments are remarkably homogeneous. The skeletons of microscopic plants and animals rain down (more of a very light drizzle) continuously from such organisms as foraminiferal frustules, pterapod shells, diatom frustules and radiolarian spicules, forming the great, almost endless sediments we find here.

Because of the unchanging nature of this environment which was relatively stable for hundreds of millions of years, it was thought in the last century that all one had to do was to obtain some animals from these great depths, and you will find all the ancestral forms of life from the Cambrian to the present day. The famous Challenger expedition was largely financed on this hypothesis. And this of course did not prove to be the case since Darwinian selection is at work in the deep sea as it is in any other biologically inhabited region of the globe. However, the classical concept has been that the fauna of the deep sea represents one of the most extreme examples of depauperization of animal life, both qualitatively, that is, there are very few species there, and quantitatively, that is, there are very few animals there.

Today I would like to examine three premises with you. The first premise is that the deep ocean supports a numerically small number of animals, that is, it has a low density. The second is that these animals are represented by a small number of species, that is, there is low diversity. The third premise is that these few species are found uniformly throughout the abyssal regions of the world, that is, there is no stratification, no zonation.

Let me now touch very briefly on the quantitative aspects--the first premise--that there are few animals in the ocean depths. When compared with other marine benthic environments, the deep-sea benthos (this is the deep-sea community of animals) does support very reduced populations. That seems to be true.

However, by obtaining larger quantitative samples and using smaller size screening mesh which retains more animals, we have been able to collect many more deep-sea animals than in any of the previous investigations. If you can imagine that the animals in nature are distributed in such a way that the larger animals are fewer in number than the smaller animals (this is called the pyramid of numbers and may be represented by a pyramid with a few large animals on the top and many small animals on the bottom) then the selection of a fine screening mesh allows one to collect a statistically large number of animals, including many smaller ones. As a result of our doing this, we collected many times the number of deep sea animals than had previous studies. The significant point of this is that we were able to obtain statistically large enough numbers of animals which allowed us to make generalizations about the deep sea bottom fauna. We did indeed find that the numberical densities of life in the deep sea bottom are much lower than other benthic regions of the ocean but many times greater than we had previously thought.

Let's go now to our second premise, that the benthic animals living in the deep sea are represented by a very small number of species. We have just said that the numerical density of life on the sea floor is fairly low. The trick then is to get large numbers of individuals from an area of low faunal density. The vast majority of deep sea animals have in the past been collected by coarse mesh trawls or dredges that moved on, rather than in, the bottom. As a consequence, our concepts of the nature of deep sea fauna are based almost entirely on the larger epifaunal animals (those living <u>on</u> the sediments).

In order to provide basic information about the smaller epifaunal animals and as a basis for comparison with samples of infaunal animals (those living <u>in</u> the bottom), we constructed a device called an Epibenthic Sled. It's a very simple affair with runners on both sides and a wide open mouth. As it is dragged along the bottom, it scoops up and sifts the top centimenter of the bottom sediment. We have had extremely good success with this sled, although, as so often happens in working in the oceans, some of our recent "improvements" to the sled have seemed to hinder rather than improve its performance.

Prior to our work, the richest sample of deep sea marine life had been collected in the mid-1950's by the Danish <u>Galathea</u> expedition at a depth of 3570 meters in the Pacific Ocean off the coast of Central America. Their sample was truly remarkable when compared with earlier samples of deep sea bottom life. It contained about 2100 individuals representing 132 species in the one sample. This sample also brought to light the remarkable primitive mollusk, <u>Neopilina</u>, a member of a group previously known only from Cambrian time.

By comparison, let's look at five samples collected by our Epibenthic Sled. At a depth of 1500 meters we collected, in one sample, about 22,000 individuals representing about 400 different species. Another sample at 2500 meters collected about 2500 individuals representing 240 species. One sample at 2900 meters contained 6000 individuals with 296 species; another at that depth yielded almost 2200 individuals with 194 species. Our sample from 2700 meters contained more than 3500 individuals with 191 species.

These five samples have added about one-third to all the known deep-sea amphipods collected over the last hundred years, and the same sort of thing can be repeated for other groups. Among the asellate isopods, about 90 to 95% of the species we get may be new. In the bivalve clams possibly

60% of all the species may be undescribed, and most of the animals below 3000 meters are new. We do find species that we recognize from the shallower slope areas of 1000 to 2000 meters. This suggests that we know little about the remarkably diverse fauna living in this environment. I think we can say, therefore, that the deep sea benthos is far from being qualitatively impoverished, and instead is represented by a remarkably diverse fauna.

Let's now consider the third premise we put forth at the beginning; that the benthos of the deep sea forms a single impoverished community. If this is the case, we should expect to find those species living there to be very broadly and uniformly distributed.

As an example, let's consider a series of deep sea samples collected along a transect from Woods Hole to Bermuda. We wish to determine whether there is a single association of animals living on and in the sea floor, or whether the population is zoned, either geographically or by depth. If indeed it is zoned, we should expect to find a high degree of similarity in the sample composition of neighboring stations but very little similarity between distant stations; a uniform community would of course provide a very similar sample composition at all the stations.

The evidence, based on an analysis of 264 species of Polychaete worm and almost 14,000 individuals, is clearly that zonation does exist. The species are not uniformly distributed along the transect, but are layered or zoned according to the depth of water at which the samples were taken. The analyses of the isopods, amphipods, and bivalves show precisely the same phenomenon.

Finally, we can summarize by saying that our quantitative results show a modest number of animals living in the deep sea, but appreciably more than it had been thought in the past. Our samples also show a rich and diverse fauna. And finally, our findings provide strong support for the contention that the deep sea benthic fauna is layered or zoned with depth.

Current Oceanographic Research in the Physical Sciences

Dr. T. Ferris Webster

Dr. Sanders, ladies and gentlemen: It is my intention to provide you today with a brief summary of some of the current oceanographic research in the physical sciences. Rather than concentrate on any particular research problem, I will present a brief synopsis of some aims, attitudes and recent trends in general physical research in the oceans.

I would like to begin with the observation that oceanography is not in itself a science. Certainly, physical research in the oceans is not physics as we know it in the laboratory, practiced in a salt water environment. Rather, oceanographic research deals with a set of problems having aspects which are unique to the ocean. It is generally true that oceanic research must proceed on an interdisciplinary level with the joint knowledge contributed by scientists in many fields.

For convenience in looking at the general field of physical research in the oceans, I have divided the research into three broad categories: The first category includes those studies whose aim is the description of the properties of the ocean; the second group includes those studies whose aim is to describe the motion of the fluid in the ocean and the distribution of properties in the ocean. (There should be a distinction between the distribution of properties and the study of the properties themselves, because there is a different type of approach in each case.) The third category includes those studies whose aim is to illuminate processes and phenomena controlling the motion in the ocean, the boundaries of the ocean, and the distribution of properties.

An example of the first research category (the description of the physical properties of the ocean) is the study of the ocean basins. The shape of ocean basins, the structure of the crust beneath the ocean, and the forces within the earth which control the shape of the ocean basins are studied by geophysicists. Geophysicists have long been aware that the nature of the earth's crust beneath the seas is fundamentally different from the nature of the earth's crust beneath the continents. Thus, it is not fair to say that geophysics at sea is just ordinary geophysics from a boat. In fact, there are unique problems, and the excitement in this field today is largely due to the feeling among oceanic geophysicists that through their studies they may turn up something fundamental about the processes going on within the structure of the earth itself.

Investigations into the physical properties of sea water are focused upon such things as the density and compressibility of sea water, the thermodynamic properties of sea water, the properties of freezing and evaporation, rates of evaporation, the formation of sea ice, the structure of ice when it is formed, and such things as the propagation of light and sound within the fluid medium.

Chemists in turn tend to concentrate on the composition of the fluid. This is a physical science, but in practice--certainly as practiced here at Woods Hole--it tends to be more closely connected to biological studies than to other physical studies, possibly because the concentration of nutrients is so closely linked to biological activity.

The second broad category of research carried out within the physical sciences is the study of the motion of the fluid and the distribution of properties in the sea. This broad category comprises what has traditionally been called physical oceanography and is one of the central disciplines in the study of the ocean. The physical property of the ocean whose distribution has been most extensively studied is temperature. The concentration of dissolved salt in the sea, or salinity, is generally closely related to the temperature. The physical oceanographer is able to use these two variables as a water-type label. By a close investigation of the relationships of the temperature-salinity labels at different points, it is often possible to trace the history and movement of ocean waters on a large scale. This classical method has provided most of our present ideas about the distribution of currents at great depths.

An alternative approach to the study of large-scale current patterns is to measure ocean currents directly. In the past, direct measurements have been largely limited to the surface areas of the oceans. Such surface studies began perhaps one or two centuries ago with observations by sailors of the drift of their ships. However, in the last few years there has been an increasing effort aimed at the direct measurement of currents beneath the surface of the ocean. As such investigations have progressed, there has been a growing awareness of a greater degree of complexity in the pattern of deep ocean currents than has been previously realized. As more complexity is discovered, the effort to understand large-scale patterns is often diverted to a study of the complexities. These complexities are interesting in their own right and may be of fundamental importance in the dynamics of the oceans.

Ocean waves have long been observed, but only at the surface of the ocean. Internal waves, which exist beneath the surface and are associated with the stratification of density, are now receiving increasing interest. As with deep ocean currents, internal waves are not well understood. Their direct observation and measurement has become feasible only with the development of modern techniques. Waves within the ocean will continue to receive increasing attention.

Tides are another form of oceanic motion which have been studied in great detail. Nearly all of our knowledge about tides is limited to tides at the surface along the shores of the oceans. Again, the present trend is to study the tides away from shorelines and beneath the surface. It seems that every time we return to the deep sea we find that we do not really understand phenomena which we thought had been understood reasonably well, or that there is particular significance in motions of the deep sea which previously had been overlooked.

The third class of physical oceanographic research is directed to an understanding of the processes controlling the motion, boundaries and properties in the ocean. Research of this type attempts to find answers to questions like: "Why does the ocean move as it does?" "Why are the oceanic properties distributed as they are?" "How do the forces acting on the ocean--winds, gravity, heating, precipitation and evaporation--interact with the water in the ocean and the shape of the ocean basins to produce the patterns of physical processes which we observe?" These problems are generally attacked on two fronts: experimental and theoretical. Experimental studies are measurements of such things as the flow of energy between wind and waves, or between wind and ocean currents, or measurement of the forces themselves which act on the ocean--heating, cooling, evaporation, precipitation. Our ultimate understanding of the dynamics of the ocean will only be as good as our measurement and description of all these processes.

Theoretical research is generally directed toward abstracting basic processes and representing them mathematically. Knowing the forces acting on the ocean and the general response of the ocean to them, the theoretical physical oceanographer attempts to construct mathematical models which will explain and perhaps even predict the state of the ocean. Parallel research is often conducted in the laboratory using models whose aim is to represent selected oceanic processes. The real ocean is usually far too complicated to isolate individual processes, but it is often possible to do so within a controlled experiment in a laboratory model of the ocean. Experimental models may range from large rotating hemispheres to very small simple boxes in which small-scale geological processes, for example, are modeled.

An interesting result from the studies of oceanic processes is the similarity between the solutions and theories that oceanographers have developed about the dynamics of the oceans, and those that the meteorologists have developed for the atmosphere. Even more interesting perhaps, is the similarity between problems and solutions that astrophysicists have developed for the dynamics of stellar bodies, that geophysicists have developed for the dynamics of the earth's interior, and that oceanographers have developed for the dynamics of the oceans.

I would like to conclude with a short discussion of some recent developments which differentiate physical research in oceanography today from that practiced a generation ago. Such a discussion may provide us with some clues as to how the science may further evolve in the next few years.

A significant new discovery in the last ten years has been that the deep waters of the ocean are not quiescent. In fact, when new methods were developed to measure deep ocean currents, it was found to the physical oceanographer's surprise that actual measurements of instantaneous currents were perhaps ten times greater than would have been expected from the classical methods of using temperature and salinity labels. That is, there are variations in deep ocean currents which are perhaps ten times greater than the average current over a period of time. This fact has had fundamental implications, and these implications are far from fully explored at the moment. However, one might generalize and say that physical oceanographers are becoming increasingly aware that variations in the ocean, such as are represented by these high velocity fluctuations in the deep sea, are basic to the general dynamics of the ocean. A direction of increasing effort in physical oceanography will therefore be to develop experiments, tools, techniques, and theories to describe the complexities which we know now to be super-imposed on the classical, simple current patterns.

New tools and techniques will assist in developing new attitudes towards physical oceanography. In the case of the complexities in the pattern of oceanic structure, it is likely that several classes of instruments will be of importance. One class consists of those instruments which are adapted to rapid surveys. An example of a fairly old instrument of this type is the bathythermograph which can be used to undertake a rapid measurement of temperature in the upper layer of the ocean.

Another class of new instruments consists of those which measure continuously in space. Instruments which record continuously while being towed through the ocean, and instruments which record continosly while being lowered over the side of a ship are examples of this type. Their value lies in their ability to provide a description of oceanic variability over a wide range of spatial scales. Instruments which merely measure at discrete points in the ocean can often overlook small-scale features of great importance.

New methods of navigation have had a strong impact on the kinds of experiments which physical oceanographers carry out. It is important for a physical oceanographer, if he is to be systematic, to be able to return with precision to the location of a previous observation. New methods of navigation now under development promise that this fundamental problem of oceanography will be lessened in the future, thus allowing more systematic experiments to be carried out.

A combination of all these new methods--rapid surveys, continuous measurements in space, and accurate navigation--will allow oceanographers to obtain an approximation to a snapshot of what some region of the ocean is like at an instant in time. A systematic repetition of this procedure should yield a description of the evolving patterns of some region of the ocean. This description in turn should provide a valuable basis for a more complete understanding of the dynamics of oceanic processes.

The large amount of information which surveys of the type just described will produce can probably be handled only with the aid of highspeed digital computers. With computers, experiments which even ten years ago would not have been conceivable can now be carried out. For example, millions of measurements can be collected in a systematic manner throughout the ocean, and high-speed digital computers can be used for their analysis and correlation.

As for the general future outlook, there will probably be an increasing effort on the part of physical oceanographers to understand the space and time variations within the broad oceanic patterns. Furthermore, there is going to be a stronger effort in the future on the part of the theoretician to develop generalizations and abstractions which describe oceanic processes, and a parallel strong effort on the part of the experimentalist to provide more precise descriptions of the state of the ocean.

New Techniques in Oceanographic Research

Dr. Nick P. Fofonoff

In thinking about the topic for this afternoon on "New Techniques in Oceanographic Research" I had to make several decisions; one of them was how to limit the talk to half an hour. I would therefore like to qualify the title somwhat to say "Some New Techniques in Oceanographic Research". Even further, the techniques I will talk about are primarily in physical oceanography, the field that I am working in, and hence, the field in which I am most qualified to talk. In talking about new techniques, I would like to restrict myself to techniques that are being presently developed, as opposed to relatively new techniques that are in routine use at the present time. I would also like to point out some trends in oceanography and to give some feeling for the direction that physical oceanography will develop in the next few years.

A very strong motivating factor in the development of oceanographic techniques has been the magnitude of the descriptive task before us. The ocean has an area of about 140 million square miles, this is the world ocean. If we were to make measurements every 100 miles in a grid covering the ocean, we would require about 14,000 points. If we think of these in terms of the classical type of oceanographic observations which are called hydrostations (where we lower a set of Nansen bottles and thermometers on a wire to take samples from the surface to the bottom) we would require 14,000 such stations to cover the ocean on a 100-mile grid. Now again, thinking of hydrographic stations, each station might generate about 200 numbers. This is about all the numbers that one can put on a page, so that such a description of the world ocean would produce a book of some 14,000 pages. Now, of course, the ocean is not a static body; it is continually changing. If we could get such a book issued once or twice a week we would have a reasonably good description of the ocean, but we immediately run into a problem. If one subscribes to a 14,000 page book that arrives once a week, one wouldn't have time to read it. So collecting information about the ocean in quantities that would be adequate to describe it is, in a sense, almost self-defeating because the information is just too vast for any individual to assimilate. This is one of the factors that has stimulated a great deal of effort and work in other methods of accumulating and assimilating or digesting measurements that are taken at sea.

In particular, the introduction of computers into the field of oceanogaphy is something that has happened within the last ten years, and only within the last five years have they begun to be used extensively. Computers are a very important modern research technique which will become even more important in the future. Even at present, there are a number of measurements that are being made that would be impossible without the use of computers. The General Electric 225 Computer has been at Woods Hole since 1963. It is already inadequate for some of the tasks we are attempting, and in the near future we hope to have a computer that is perhaps 20 or 30 times as fast and as powerful as this system.

The use of computers obviously cannot be restricted to the laboratory. For example, Carl Bowin at this Institution has been developing a computer system that goes to sea. Obviously, this computer is capable of receiving information at many times the rate that a human being can accept, digest and interpret it, and therefore it seems a natural and obvious step to take a computer, put it on a ship, and take it out to sea. Of course, there are many problems that arise and have to be faced in the development of measuring systems that can collect information at a rate comparable with a computer, and the system has taken considerable time to develop.

Such a program at sea makes very efficient use of the ship for the type of observation that can be collected in this fashion. It can, in some cases, depending on the type of equipment associated with it, tell us the temperature of the water, the salt content, or where the ship is; it can measure gravity and magnetic field; it can even tell us something about the currents in the local area. It can collect this information at many hundreds of times the rate that a human being can collect it.

The computer can display the data in the form of graphs or of summaries that are more accessible to human beings than a raw list of numbers, and it's done automatically by the computer. These types of applications will develop much further in the future; they are clearly the way we have to go if we want to get descriptions of any sizable part of the world ocean. The techniques therefore are tending toward the development of systems with multiple sensors in which data about a great number of variables is automatically collected, processed, and plotted. Eventually, it will be reduced to a size that can be comprehended by a human being.

The oceanographer must of course go out to sea. He cannot make all his measurements in the laboratory, and therefore, he requires vehicles of various kinds to carry himself and his instrument out into the ocean. I would like to spend a little time discussing some of the vehicles that have been developed, because again the new techniques that are now being used are essentially based on the development of a vehicle to take either man himself or instruments out into the ocean.

One of these vehicles for carrying instruments into the ocean is shaped like an inverted "V" and is called appropriately a "V-Fin". The device is hydrodynamically shaped and is towed behind the ship. Its primary purpose is to carry a temperature sensing element, and to keep it submerged as the ship goes along.

This instrument is used to determine the position of the Gulf Stream. The device is towed behind the ship; the temperature element senses the temperature at a certain depth; and from the distribution of temperature one can trace out the pattern of the Gulf Stream. It is a very selective way of going out and finding the Gulf Stream. Another way to do it, for example, would be to take hydrostations at closely spaced points throughout the Gulf Stream region. One would need a great many stations, and it is somewhat like that story that one finds in many math books about lion hunting in the Sahara Desert. One way of doing this is to sift out the sand and you would be left lions. That appeals to mathematicians, because in fact, it's a very comprehensive way of getting all of the lions. But of course, it is not a very practical way of looking for the Gulf Stream. One needs a much more selective way of looking at and determining the position. This is one method that has been developed and has worked successfully.

There are a lot of pitfalls in developing such devices. I might just point out one--that a great problem arises simply in towing a cable through water. It tends to vibrate rather strongly if it is towed at any speed through water. On the "V-fin" we use a cable with hair on it; it is for minimizing the vibration of the cable as it is being towed through the ocean. Often a technique will depend on the development of some very minor part of the system such as this hair on a cable to make it work effectively in the ocean.

Another vehicle, and of course a very well known one, is our little submarine ALVIN. It not only takes instruments into the ocean but man himself. It is an extension of the direct capability of man to involve himself in the environment which he is studying. Of course, a platform or vehicle like the ALVIN appeals to the adventurous spirit within us, and I think it is an extremely exciting development in oceanography to be able to have man enter the ocean and see for himself, effectively. This is a peculiar thing about the ocean. For example, in the atmosphere one can look around and develop a very close feeling for events in the atmosphere just from living in it. This has never been the case in the ocean; one just doesn't develop this intuitive feeling in the same way that one does in the atmosphere because one simply is not living in it. Vehicles such as the ALVIN will help us to see and feel the ocean in a different way than we have before. I think that vehicles like the ALVIN are going to have an exciting future in oceanography.

A different type of platform we use is a deep-sea moored buoy. This is used to hold instruments in the ocean for extended periods of time. In one case the mooring is located south of the Gulf Stream in 15,000 feet of water. A cable extends from the float to an anchor on the bottom--about 3 miles--and instruments can be suspended at any level below the surface. This is one example of quite a large variety of deep-sea moorings that are possible. Some of them that are used are completely below the surface and are not seen at all. These are particularly useful for measuring currents since a mooring of this type is not exposed to surface waves.

Deep sea moorings will be used a great deal in the future because they give us an ability to take measurements over extended periods of time with basically unattended systems. We can transmit information from these buoys to shore and eventually perhaps major parts of the ocean will be sensed by systems similar to this. Buoys, because they are anchored and stay in one place, are primarily used to study variations in time of the ocean--the way the temperature field and the currents change with time. Measuring changes with time eventually will lead to the ability to predict what is happening in a given area of the ocean.

There is one other class of instruments I would like to mention. These are free floating instruments that will sink below the surface of the ocean but not reach the bottom. They will reach an equilibrium at some intermediate level and will then follow the currents at that level. This type of float was developed some ten years ago by Dr. Swallow in England and recently has undergone an interesting development or evolution. In one particular case, it is being designed to signal over a very large distance. The transducer hopefully will send out a signal that can be detected as much as 800 miles away; and if that turns out to be the case, it will be possible to track these floats from listening stations near the coast almost anywhere in the western north Atlantic. This capability would give us the ability to measure the currents and gain an insight into their mechanics.

Another direction of development of similar floats is an instrument that was developed here by Douglas Webb in collaboration with Valentine Worthington. It is an example of a new instrument--an attempt to measure vertical currents in the ocean. This device is again a neutrally buoyant float, that will sink to some preselected level in the ocean. It has vanes that are designated to make it sensitive to extremely small vertical motions of the water; and it is designed with internal electronics to send out signals that can be read at the surface to determine the rate of rotation of the instrument with respect to the earth's magnetic field.

There will be many more such devices developed in the future to look at specific aspects of the ocean's behavior. For example, further evolution of these floats could be to have them be slightly more dynamic in their capability of maintaining a given level in the ocean, perhaps by changing their buoyancy automatically. Instruments of this class are being developed.

That is a very limited selection from present day techniques, and I do not pretend that it is comprehensive; but I hope that it gives you at least a feeling for some of the techniques that are being used and developed in oceanography.

Oceanographic Manpower Needs

Dr. William G. Torpey

There is a shortage of qualified oceanographic manpower. The shortage is particularly acute with respect to individuals capable of exercising imaginative scientific leadership in oceanography. Although the number of students in oceanographic programs and related courses has grown during the past few years, evidence presently available indicates that the growth in the numbers of those being so educated is failing--and will continue to fail in the immediate future--to meet demand, both quantity-wise and quality-wise.

An educational and employment profile of individuals engaged in oceanographic work was made by the Interagency Committee on Oceanography of the Federal Council for Science and Technology as a result of a study by the International Oceanographic Foundation in 1964.

Data obtained from 3,693 respondents in the IOF study indicated that 2,649 persons were engaged in scientific and technical work in oceanography in 1964. It was believed that at least 90 percent of those who could have met the criteria for such work were represented in the survey. On this basis it was estimated that slightly less than 3,000 persons were doing scientific and technical work in oceanography in 1964. Of the 2,649 persons whose responses were analyzed in the IOF survey, 35 percent, or 929, were judged fully qualified in the sense that they could perform or manage high-level work in the oceanographic area. This group included 631 oceanographers, 171 fisheries management specialists, and 127 oceanographic engineers. Over a fourth (464) of the 1,720 not-fully-qualified group were students, and about another quarter (423) of the 1,720 were in an intern status (no specialized training or extensive experience in oceanography or fisheries but usually with some degree of professional training and accomplishment in the sciences). From the viewpoint of formal education, excluding students, about 25 percent had doctorates and 22 percent had masters degrees. About 64 percent of the university respondents had doctorate or masters degrees. About 35 percent of the respondents in federal, state and local agencies possessed masters or doctors degrees.

With respect to occupational classification, of the 631 oceanographers in the IOF survey, 312 were working in the biological science area. The remaining 319 were employed in the physical science area. Of the 2,649 in the survey, 482 were employed in physical oceanography. Of these, 99, or 21 percent, reported that, although they were working in this area in fact, their principal competence was in a field other than physical oceanography.

Basic research was either the primary or secondary work activity of most of the respondents of the IOF survey. The exceptions were fisheries (management) specialists and oceanographic engineers who tended mostly to applied research. 166 or 52 percent, of the 320 oceanographers in universities reported teaching as either a primary or secondary work activity. Basic research predominated among the 48 percent remainder in the university group.

Twelve to 20 percent of the individuals covered in the IOF survey had never been to sea. Eighty-three percent of the 2,649 were employed full time in oceanography. Of the 464 students, 318 were attending universities which offer both specific curricula and degrees in oceanography. Twenty-seven of them had already qualified as oceanographers by reason of having earned a masters degree in the marine sciences.

Consideration of results of this survey indicates an extremely varied pattern of education and background of the national pool of oceanographic manpower and suggests that improving the quality and quantity of oceanographic manpower could well be a national manpower goal. This goal is a vital challenge to those involved in ocean science education at every level of education--primary, secondary, and collegiate and post graduate.

The National Oceanographic Program for Fiscal Year 1967, projected by the Interagency Committee on Oceanography and released in 1966, provides an analysis of manpower implications of the FY 67 program. The ICO analysis points out that federal obligations for oceanographic research and surveys increased from $85 million in 1964 to $97 million in 1965, to $109 million in 1966 and to an estimated $121 million in 1967; this increase represents a 1967 expenditure level for research and surveys of 42 percent over 1964.

Manpower requirements for FY 1967, the ICO report states, should increase by roughly one-third over the 1964 figure; the net result is to approximate total professional staff requirements in the vicinity of 4,000 by the end of FY 1967. The ICO analysis indicates that although there has been growth in potential manpower supply, as evidenced by graduate enrollments, "actual manpower supply from oceanographic degree holders is smaller than present program requirements and makes necessary the continuing recruitment of staff from fields of biology, geology, engineering, etc., as in the past." So long as opportunities in oceanography continue to attract staff from the other sciences, the report observes, there is relatively little difficulty in meeting requirements in the quantitative sense. However, recruitment from these sources does require a significant program of supplemental training to make effective use of such recruits. One constructive solution is to increase the availability of appropriate courses and programs in the ocean sciences--a solution which is a theme of this conference.

Federal support for graduate training in oceanography may be classified as (1) fellowships and traineeships awarded for graduate training; (2) formal programs to provide supplementary education and training to federal employees; and (3) research grants and contracts to universities which employ graduate students as research assistants. The accompanying table presents a three-year analysis of such support:

Type of Federal Support	Number of Federal Agencies Supporting	Number of Individuals to be Trained FY 65	FY 66	FY 67
Fellowships and Traineeships	3	195	193	225
Training of Federal Personnel	4	291	319	326
Research Grants and Contracts	7	520	601	753
		1006	1113	1304

Examination of the above figures shows that training opportunities provided by federal support at the collegiate level has increased. It must be realized, too, that federal support is only part of the total increased support provided for education and training in oceanography. However, as extensive as such total support may be, evidence indicates that total current efforts are not sufficient to provide adequate numbers of quality personnel in specific specialties for the present or immediate future. The long range view for challenging worthwhile employment in the ocean science field appears to be excellent.

Earlier this month, the Navy Oceanographer testified before a Senate Subcommittee as follows: "Everyone associated with oceanography today feels the impact of the acute personnel shortages involved. This same holds true for many other fields, but I doubt they can also claim the general lack of university-type training which exists for the young man or woman about to enter this limb of scientific endeavor. These shortages are felt throughout the entire oceanographic world but at present appear to be most acute in the disciplines of physical and chemical oceanography. The governmental, industrial and academic communities are all clamoring for additional personnel to fill the gap." Other witnesses before Congressional committees looking into the subject of oceanography during the past 18 months have given similar testimony on the seriousness of shortages of competent manpower.

Educators, such as those in attendance at this New England Conference on Ocean Science Education, are in a strategic position at this timely period to stimulate more interest in, and provide additional opportunities for, education in the range of scientific and technical positions associated with oceanography. In pursuit of such education, students--both young and old--will be developing and strengthening their abilities to carry on in a very vital area of the national interest. These individuals--as subsequent professional and sub-professional personnel in industry, in government laboratories and in educational institutions--will be able to make scientific and technical contributions and reap benefits therefrom. The States will also benefit. So will the Nation.

CHAPTER III

OCEAN SCIENCE EDUCATION

Ocean Science Kits and Supplementary Marine Science Centers

Dr. Clarence B. Lindquist

The recent advances in oceanography have spurred increasing interest in this science on the part of both students and teachers. The interest of students has been whetted by what they read in newspapers, magazines, and books and by what they see and hear on television and radio. Teachers are finding it necessary to know more about ocean science in order that they can answer intelligently the questions asked by their students. More and more articles on oceanography are now appearing in professional journals for teachers. For example, the entire January, 1966 issue of the American Biology Teacher was devoted to marine biology.

Because of this growing interest in oceanography, a pressing problem is that of deciding what ocean science concepts can and should be taught, and at what levels they should be taught in our elementary and secondary schools. There are even a few individuals who would like to see an entire course in oceanography taught in our high schools, on an elective basis. While almost all educators regard such a course as impractical and unnecessary, they are nevertheless acutely aware of the need for up-to-date source materials which can be used in teaching units on ocean science. To meet this need, there are a number of significant activities underway throughout the country. The members of this panel will report to you on some of these major activities in some detail. I shall only briefly describe several activities which are not being reported on by the other members of this panel.

First, there are the two kits, one on oceanography and the other on Sea Lab II, produced by the San Diego Department of Education, San Diego, California, in cooperation with the U.S. Navy Electronics Laboratory and the Office of Naval Research, respectively. Each kit consists of a sound filmstrip study guide, a teacher's manual and charts and photographs. I understand that these kits are being used by a large number of schools in California. The aim of these kits -- there are others besides those relating to oceanography -- is to reduce the time lag between a scientific achievement and the teaching about it in the classroom. It is said that it takes about 10 years for new discoveries or new facts to appear in textbooks.

Another kit that has been developed for educational use is "Understanding Oceanography," produced by the Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Illinois. The kit consists of 6 full-color filmstrips with accompanying record and a teacher's guide.

The next kind of activity in ocean science education which I wish to describe is Title III, the Supplementary Educational Center and Services, of the Elementary and Secondary Education Act of 1965 (P.L. 89-10), which authorizes use of Federal funds to assist local schools in providing needed educational services not available in sufficient quantity or quality and in developing or establishing exemplary programs to serve as models for regular programs. In the first two competitions with deadline dates of November 10, 1965, and February 9, 1966, four projects for supplementary centers devoted exclusively to marine science were approved. Two of these four centers are located in New England, one in Maine and one right here in Falmouth that Superintendent Merson of this panel will tell you about.

The other three centers are located at Kittery, Maine; at Beaufort, North Carolina; and at Inverness, Florida. There are representatives at this conference from each of these Centers, and I am sure that they will be happy to answer any questions you may have about them.

The project in Kittery, Maine, is at the Robert W. Traip Academy, which received approval for a planning project for a Regional Academic Marine Program. Special facilities and programs have been planned for offering learning experiences in the marine sciences to the children and adults of the schools and community. Among the programs considered were an introduction to marine plants and animals for elementary school pupils; advanced science courses, introduction to, and career orientation in, marine sciences; opportunities for individual projects for secondary school students; summer institutes and marine science workshops for teachers; an instructional program for adults; visiting lecturers; marine aquarium facilities; and a traveling laboratory and museum.

The Cartaret County Board of Education at Beaufort, North Carolina received approval for a project titled, Development of a Unique Educational and Cultural Marine Science Center. A marine science center was planned to include a specialized environment, instruction, and equipment; radio and television programs; public displays; educational services for adults; and teacher institutes.

The Citrus County Board of Public Instruction at Inverness, Florida, received approval for a planning project titled, Marine Science Station. A program was planned in which living specimens were to be collected and delivered to schools and junior colleges. Marine plants and animals and geological, meteorological, chemical, and physical characteristics of the oceans were to be displayed.

In addition to these centers devoted exclusively to marine science, at least three other centers have ocean science activity as a component of a broader program. These three centers are located at Sarasota, Florida; Corpus Christi, Texas; and Middletown, New Jersey. Perhaps, more ocean science centers devoted either exclusively or partially to ocean science education, will win approval under ESEA Title III.

Oceanology in the Elementary School

Dr. Thomas E. Moriarty

In spite of the fact that the oceans of the earth have fascinated man throughout the centuries, limited attention has been given to any organized study of oceanology in either the elementary or the secondary school. Even today when considerable emphasis is being placed upon developing and implementing new science curricula for the elementary schools, oceanology as an organized area of study is receiving limited attention. Any organized or integrated study of oceanology still remains beyond the secondary school.

If the oceans constitute one of mankind's greatest resources, if many phases of human life are influenced by the sea, and if the safety and welfare of the United States and the world depend upon a knowledge of the oceans, then to delay the awakening of an interest in oceanology in the minds of young people remains a shortcoming in our educational program.

With an interest in these problems, with a desire to introduce some organized study of the oceans into the elementary school, and with encouragement from the Link Foundation (and in particular Miss Marilyn Link) I agreed to survey what directions, if any, existed in the study of oceanology in the elementary schools, to determine the nature of the resources available, and to develop some guidelines that might be of use to teachers in the intermediate grades--4, 5, and 6.

I have compiled these findings into a series of resource units on the basis of interviews with teachers and scientists, a review of the literature, and a review of science programs in the elementary school. The findings are reported in "Oceanology for the Young-- A Teacher's Guide."

The document suggests that the objectives of a curricular program in oceanology should be: (1) to provide information and experiences which will familiarize children with the marine environments; (2) to develop appreciation of the ocean as a major source of food; (3) to acquaint children with methods of inquiry used by the marine scientist; (4) to correlate marine science with other phases of the curriculum; (5) to develop positive attitudes toward marine conservation; and (6) to develop an awareness of careers in oceanography.

These objectives should be realized through reading, lectures, demonstrations, class discussions, independent projects, experimentation, viewing films or filmstrips, field trips as well as any other methods that are used in the teaching of sciences. As with any aspect of science education, teachers must help children learn basic science information, principles, and generalizations. In the process the children acquire methods of scientific inquiry, how to make hypotheses, collect facts, test their findings, draw conclusions, and make applications. In teaching marine science specific problems of an interdisciplinary nature normally serve as a frame of reference for inquiry.

A program in marine science should consist of a sequential series of experiences so that concepts will be developed and expanded as the child moves through the intermediate grades. In grade four, children can be introduced to the oceans and the animal and plant life found in the sea. Grade five should build upon this work in presenting material related to the seashore, resources of the sea, and classification of plants and animals. Grade six can move into a study of the moving sea, formation of the oceans, research and conservation. Due to the difficult task of relating the many interrelated factors of studying about the sea, definite boundaries for units or areas of study are difficult to establish. As a result, it is the responsibility of the teacher to be resourceful and to build experience in keeping with the children's interests and abilities.

The program in marine science must be carefully integrated with the existing science program and serve to strengthen it. The units of study reported in Oceanology for the Young should serve as guidelines and suggest: (1) some of the common learnings dealing with the oceans, animal and plant life, the moving sea, the seashore, and ocean floor, conservation, resources, recreation, and research; (2) some suggested pupil activities in each of these areas; and (3) a bibliography.

In general, subject matter is placed in the curriculum to achieve some established purposes or aims. As in the case of oceanology, subject matter has a tendency to lag behind aims. As the new content is added it must be carefully articulated with the existing science program. At this point the placement of the material as well as its difficulty level must be carefully considered.

Leading science educators do not agree on one list of topics or areas suitable as science subject matter for the elementary school. The specifics of what children should learn in science remain debatable. The debate revolves around whether the content should be organized around big ideas in science, problems of pupil interest or local importance, or organized to give pupils a glimpse of the commonly recognized major divisions of science.

In the elementary school, a study of oceanography offers not an area of specialization but one of diversification. It is intimately connected with every pure science and with each of the social sciences. It provides for experiences which demonstrate basic scientific principles and critical thinking.

Another problem revolves around grade placement and sequence. Even though one may ascribe to the idea that pupils should progress as freely as their development and achievement will allow, teachers must be concerned with the relationship between the developmental stage of the individual and the educational experiences he is to have.

If children are to mobilize their knowledge and integrate their energy output into an effective learning pattern the subject matter must have meaning for them as well as be presented at a time in their educational career when it can be learned most effectively.

Factors influencing sequence, such as maturation, usefulness, experimental background, difficulty, and mental age must always be considered when content is added. The aim here is to weld the development of the individual with experience and content. To help resolve these problems we not only need the skills of the elementary school teacher and the body of knowledge accumulated by specialists, but research studies dealing with content and its sequential placement in the curriculum. The success of this program is primarily the responsibility of oceanologists and their communications with teachers. Here I am not talking about the type of scientists who concluded that the only oceanological concepts which should be included in the elementary school science is wave motion.

For example, one study we just completed at the University of Rhode Island tested the hypothesis that there is no difference between the number of facts learned by pupils who live near the ocean and those who live in Kansas. It was concluded that no significant differences in learning could be attributed to geographic location.

Although many stimulating and alert teachers are attempting to include more subject matter dealing with oceanology, I found current science texts being used in the elementary school inadequate in terms of presenting concepts in the marine sciences. Reference materials for teachers as well as curriculum guides are in extremely short supply. In general, the science programs just do not provide any organized content dealing with the wide range of concepts in oceanology.

In spite of these shortcomings the teachers are rapidly changing the picture. This is an outgrowth of the national interest in oceanology, the increased availability of audiovisual materials, and the variety of publications available from government and private sources. Actually coverage in newspapers and popular magazines has been the teachers' richest resource. In addition publishing companies are producing more library books on appropriate levels of reading and understanding.

But even though a large number of schools devote time to oceanological concepts through experiments, short term units, current events, films, stories, aquaria, or field trips, there isn't any organized area of study which goes beyond a few concepts such as the water cycle, temperature control, and tides. As a result these experiments give rather incidental treatment to oceanology rather than being directly related to basic curricular objectives of the science program.

Professional journals commonly read by elementary teachers have been devoting more attention to providing teachers with essential background information. However, the professional journals dealing with oceanology are for the most part too technical for use by the elementary school teacher. We need individuals who will serve as interlocking resource links between the accumulated body of technical knowledge growing out of the study of the oceans, and the appropriate content in oceanology for the elementary school youngsters. If properly planned, the unique contribution of marine science to the intermediate grades is that it brings into focus all areas of science and makes units in marine science logical supplements to the regular science programs. Just as oceanographers carry out their study and research from an interdisciplinary point of view, the different science backgrounds and interests of children can lead their talents in the investigation of problems and experiences in marine science.

The Ocean Science Study Kits of the U. S. Naval Oceanographic Office

A. R. Gordon, Jr.

In October 1965 the Naval Reseerve Association at its annual meeting passed a resolution recommending that "the Navy Department make available oceanographic educational materials to education institutions, especially high schools and libraries." The Association took this action realizing that the lack of trained oceanographers, more than any other factor, is hampering our national effort in oceanography. They believed that an exposure at high school level would encourage students to consider oceanography as a career. In response to the resolution, the U. S. Naval Oceanographic Office has produced a set of Ocean Science Study Kits for students and teachers.

The mission of the Oceanographic Office does not normally include the production of educational materials for distribution to the public. As a matter of fact, however, in the 18 years that I have been associated with the Office, thousands of school children have referred their questions on marine subjects to us. A recent letter, which is typical of several dozens the Office receives weekly, read like this:

> Dear Sirs:
>
> I am a student in the 9th grade at Center Grove High School. For our science project this year I have chosen the subject of oceanography. Please send me everything you have on oceanography.
>
> Sincerely yours,
>
> P. S. Please send the above as soon as possible since I have to turn my paper in by next Friday.

We reply to all of these inquiries, usually by sending the student a dittoed sheet of references listing books or periodicals that he can find in his school or local public library and which are pertinent to his educational level, that is, elementary, secondary, or college. If the student is politically minded and sends his letter through his congressman, the reply is on its way in 24 hours, a rule of the Office. For the student who defines his interest more precisely than the one whose letter is reproduced above, we often are able to supply a reprint or reproduction of a semipopular article written by one of our staff members. Recurring and frequent subjects of inquiry, such as the Gulf Stream, sharks, and the Sargasso Sea, are covered in this manner.

In assembling the Ocean Science Study Kits, we have had to abide by several restraints. First, we could not create new material for inclusion in the kits but were limited to those charts, publications, and other materials on hand that had been prepared in connection with the basic mission of our Office. This restraint was not as confining as might be imagined, however, because included in our mission we have the task of training foreign naval officers in oceanography as well as giving on-the-job training to our own newly recruited oceanographers. In this connection we had already prepared certain educational materials. The other restraint is that we cannot give the kits away but must sell them at cost. We want to limit the price of the kits to an amount that the students can afford and at the same time make the kits comprehensive, useful, and interesting.

We are considerably indebted to Dr. Clarence B. Lindquist of the U. S. Office of Education in helping us decide on the contents of the Ocean Science Study Kits. He worked on this problem during a two-week tour of military duty at the Oceanographic Office in January 1966. It was Dr. Lindquist who came up with the idea that we should have two kits--a basic version for students and an enlarged kit for teachers. The idea that the teacher have more background material and know more than the student had not occurred to us, but I suppose the concept is well established among educators. Dr. Lindquist's recommended student's and teacher's kits would have sold for $1.00 and $2.00, respectively. Early this spring an office committee assembled a limited number of preliminary Ocean Science Study Kits, using Dr. Lindquist's recommendations plus additional items the committee considered pertinent.

Let me now describe briefly the contents of these prototype or experimental kits.

1. <u>STUDENT'S KIT</u>

a. Pilot Chart, May 1966. Sample of a chart that has been issued to mariners for many years by the Oceanographic Office in exchange for marine observations. Pilot charts are compiled for the North Pacific and North Atlantic and give the mariner an idea of the type of climate, that is, storms, winds, and currents, he will experience over the ocean for the particular month covered by the chart. On the back of this particular chart is an article on ship groundings, which makes fascinating reading. Case histories are given for several of over 1,000 groundings that occurred in 1964.

b. Pilot Chart Articles. The following 10 articles from the backs of Pilot Charts published in recent years have been selected for inclusion in the kit:

"The Titanic - 50 Years Later"
"Oceanography and the Mariner"
"Biological Oceanography"
"Dangerous Sea Life"
"Treasure from the Sea"
"Natural Phenomena"
"Peru Current"
"The Gulf Stream"
"Underwater Disturbances"
"Water Density and Its Applications"

These articles are written at a level easily understood by a high school student, are entertaining as well as informative, and as a group cover many aspects of oceanography. A great deal of research has gone into the preparation of the articles, and they contain gems of information not found in any other single publication.

c. Nautical chart and "Nautical Chart Symbols and Abbreviations." The chart is included to show the student a sample "road map" used by mariners in making a landfall, and the accompanying booklet explains the various symbols and abbreviations used on the chart.

d. "Your Future in Oceanography." This well-illustrated booklet describes the kinds of jobs government oceanographers do and the qualifications that must be met to become a Civil Service oceanographer.

e. "Oceanographic Bibliography for Secondary Schools." An up-to-date listing of books, including paperbacks, and magazine articles on oceanography for high school level.

f. Ocean Basin Features. A chart, graphically portraying various topographic features that make up the sea floor, with definitions on the reverse side.

g. "Education for Careers in Oceanography." A reprint that tells the student how he can plan his education to qualify as an oceanographer. It also includes information on colleges and universities offering courses in oceanography.

h. H. O. Pub. No. 9, Part 6, "Oceanography." A reprint of the chapter on oceanography taken from "The American Practical Navigator," popularly known as "Bowditch." The material is of a textbook nature.

i. H. O. Pub. No. 9, Part 8, "Hydrography." A reprint of the chapter on hydrography from "Bowditch."

j. "Project MAGNET." A brochure describing the worldwide airborne geomagnetic survey conducted by the Oceanographic Office.

k. Student Exercises. These 3 exercises require the student to: (1) draw a tide curve and answer questions concerning the characteristics of the tide, (2) make a map of ocean bottom materials, and, (3) contour oceanographic soundings to produce a bathymetric chart.

2. <u>TEACHER'S KIT</u>

a. The teacher's kit contains all of the above items listed for the student's kits.

b. "Films on Oceanography." A brochure describing 58 motion picture films and film strips suitable for teaching of ocean science, many of which are available on free loan.

c. "Catalog of Nautical Charts and Publications." Catalog listing many published items on oceanography available at cost from the Oceanographic Office for supplementing instruction in ocean science.

d. "Oceanography and Underwater Sound for Naval Applications." Textual material on oceanography and its naval applications in much greater detail than is given in the publication included in the Student's Kit.

e. Pub. No. 606 Series. These four brief, but well illustrated, pamphlets give instructions for making sonic soundings, bathythermograph observations, ice observations, and sea and swell observations from shipboard.

f. "How Deep is the Ocean and Who Cares?" A reprint of an interesting talk recently given by Admiral O. D. Waters, Commander of the U. S. Naval Oceanographic Office, on the importance of hydrography and bathymetry to the ship's navigator.

g. "How Much Chart is Enough?" A reprint of a talk by Captain V. A. Moitoret, Deputy Commander of the U. S. Naval Oceanographic Office for Hydrography, which tells how a nautical chart is produced and how we decide how much information is to be included on the chart.

h. Solutions to Student Exercises. Printed on translucent paper so that student's exercises can readily be checked by overlaying.

Our object in preparing these kits was not to provide the student with a comprehensive course in oceanography but to make available to him some interesting sample material on oceanography that might stimulate him to delve further into the subject. In this connection I have reviewed the material on oceanography in the Earth Sciences Curriculum Project, and I believe that our Ocean Science Study Kits will serve as valuable supplements to that excellent course of study without duplicating its contents.

We have now assembled a limited number of experimental kits and are placing them in the hands of high school teachers for comment to help us standardize the kits. Particularly, we would like to have ideas on:

1. What items appear to be of greatest interest to the student?
2. What items are most useful as supplements to the teaching of ocean science in secondary schools?
3. Is the material in the Student's Kit of the proper level of dificulty
4. Do you have any specific suggestions on reducing the bulk of the kit?
5. Are the student exercises of value?
6. What do you feel would be a reasonable price to charge for the kits?

We would welcome your comments on these particular questions, or on the kits in general.

The Earth Science Curriculum Project (ESCP)

Dr. Ramon E. Bisque

Inspection of recent changes in science teaching at the secondary school level reveals two distinct trends; one a rejection of outmoded general science courses and the other an increase in laboratory emphasis.

The rejection of general science courses in usually related to two factors. Much of the subject matter generally included in these courses is now being treated in earlier courses and secondly, most general science courses suffer from a lack of continuity. Subject matter is presented in units which bear little relation to one another and utilize various types of approaches. The result is a potpourri of topics, held together by nothing more substantial than the binding of the book.

The emphasis on the laboratory approach is no doubt the result of a desire on the part of educators to present science as something other than a compendium of facts and figures. The scope and pace of modern-day scientific developments cannot be met with fact-oriented pedagogy. "Facts" change overnight, they become absorbed in other "facts" as knowledge increases; some are proven false. Courses structured around "telling" about facts are miserably inadequate in conveying the fundamental ideas and concepts of science. They also do not lend themselves to presenting science as inquiry. Inquiry need not be taught to youngsters. Though it may expose itself in various guises, some of which are more amenable to formal guidance than others, the desire to know is always present. Ideally, the investigative approach to science teaching should cultivate this desire and permit the student to discover things through his own efforts. The challenge to the teacher lies in using the discovery approach to initiate discussion and introduce further inquiry. This focuses emphasis on "how" we learn rather than "what" we know.

The dissatisfaction with general science courses as they were being taught coupled with the belief that earth science should definitely be part of the secondary school curriculum led to the establishment of the Earth Science Curriculum Project (ESCP) in 1963. Supported by a grant from the National Science Foundation, ESCP is an activity conducted by the American Geological Institute. Since its inception, ESCP has had its headquarters in Boulder, Colorado, and has made use of the facilities at the University of Colorado.

The principal objective of ESCP has been to produce an experience-centered earth science course suitable for the ninth-grade level. In developing this course, planners and writers have striven to demonstrate the interrelationship between the earth science disciplines of astronomy, geology, meteorology, oceanography, and physical geography. The understanding by the student of physical and chemical properties and mathematical relationships have been regarded as basic and essential in the development of course materials.

Since oceanography is one of the earth sciences, it has been well represented in ESCP from the beginning-- in the steering committee, the advisory board, the planning conferences, and the writing groups. Of the 60 writers who participated in the writing conferences in the summers of 1964 and 1965, 39 were professors at colleges and universities. Six of the 39 professors were professors of oceanography.

The writing conference in the summer of 1964 produced a text, Investigating the Earth, and a Laboratory Manual and a Teacher's Guide to accompany this text. These materials were evaluated in 77 schools during the 1964-65 school year and were extensively revised by 43 writers at the second writing conference in the summer of 1965. The revised (1965) editions were tested formally during the 1965-66 school year in 75 schools across the country and informally in an additional 300 schools with 21,000 students. Results of this testing have been used as the basis for final revision and publication in early 1967 of the hardcover version by the Houghton Mifflin Company. Two of 26 chapters of the text, Investigating the Earth, deal specifically with oceanography. Chapter 7 discusses "Waters of the Sea" and Chapter 12, "Earth Beneath the Sea."

ESCP publishes a NEWSLETTER quarterly to keep all interested persons informed of its progress. Subscription to the NEWSLETTER is free upon request. Simply mail your request to the Editor, Earth Science Curriculum Project, P.O. Box 1559, Boulder, Colorado 80301.

Why Teach Earth Science in Our Schools?

Dr. James W. Skehan, S.J.

During the past three years as one of the writers of the Earth Science Curriculum Project book, Investigating the Earth, I have had the rare opportunity of delving into the subject matter of this program to a degree that I had never anticipated. As Test Center Consultant in the Boston area, moreover, new dimensions of this Program unfolded as I was able to follow at first hand the teacher and student feedback on the materials which we had previously developed.

The goal which this Earth Science Curriculum Project has in common with all educational scientific programs is to prepare the student both intellectually and emotionally to develop those attitudes and skills which are necessary in order to make meaningful, basic observations about his subject of study. From these data, he may then be prepared to draw his own logical conclusions regarding an explanation. The aim of the Project is to provide the student not merely with information about scientific discovery, but especially to involve him or her with actual experience in discovering the secrets of the Earth. Within the broader framework of this Earth Science Curriculum Project we have been greatly concerned with oceanology or ocean science even as geologists have been to an increasing degree for over a hundred years.

The fact that a blanket of water hides almost three-quarters of the surface of our globe makes ocean science a fascinating study of the last essentially unexplored realm of the Earth. Moreover, progress in ocean science is absolutely essential to an understanding of the true nature of the Earth. As such, ocean science is already an integral part of this one new phase of our educational program today, the Earth Science Curriculum Project. I believe that a greater emphasis on ocean science education at all levels is warranted, but especially so in the broad context of Earth Science. In my opinion, the greatest benefits of ocean science in particular and earth science in general are the important and stimulating effects they have on education as a whole. These benefits, including the emphasis on firsthand investigation and personal involvement with the subject matter, will be more far reaching than the mere teaching of ocean science information to the students of our elementary and secondary schools.

The study of ocean science, as I see it, should focus on the basic stimulation of interest in the investigation of one's environment. Such a study is interdisciplinary of its very nature and requires that the student become familiar with basic techniques and principles whose resources more commonly than not are separated into compartments called chemistry, physics, biology, and mathematics. Oceanology becomes a study of one's total environment rather than the study of a fragmentary subject matter separated artificially into compartments which are sometimes constrictive and too artificial.

We regard ocean science as an extremely important part of Earth Science no matter whether we are concerened in our scientific research with the geology of the continents, with meteorology, or marine geology, for example. It used to be that we geologists learned a great deal about the ancient deeper and more inaccessible parts of our globe - the ocean and the ocean basins - from our studies of rocks exposed on the continents. But with the advances in electronic instrumentation that developed during the Second World War, the acquisition of oceanological data became much easier. It was really improvements in instrumentation which unlocked even the deepest part of the ocean basins. Now we know that it is necessary to research the ocean basins to understand more thoroughly the nature of even our continents.

Recent studies of ocean ridges and rises, of marine volcanoes and volcanic rocks of our ocean floors have gradually led us to conclude that the crust of the Earth beneath our ocean basins is the most dynamic part of our globe. Recent research partially derived from studies of the oceans seems to indicate that our continents react quite passively to movements most easily recognized in the oceans. The Earth's mantle, which is closer to the surface of the Earth beneath the oceans than elsewhere, seems to be the most active of the upper zones of the Earth. In the study of the origin and development of mountains, those who are not particularly oriented toward ocean science may think of mountains of the continents merely as the site of past deposition of great thicknesses of sediments. But the important thing to note is that most of the sediments now found in the continents have been deposited in oceanic environments. A more complete understanding of the processes at work in our modern oceans is necessary to help us reconstruct the past history of our continental masses and ocean basins.

Fundamental indications of the dynamic character of the Earth are volcanism and earthquakes. We have long been fascinated by volcanic activity on the continents. Recent research, however, has shown that volcanic activity is especially intense in the ocean basins and widespread volcanism is closely associated with oceanic rises or ridges. The geologic record has long indicated that the boundary between oceanic and continental crust is likewise a zone of great mobility, especially if sediments are accumulating there. The presence of thick, highly deformed and metamorphosed volcanic and plutonic rocks in former mobile zones now uplifted into mountain chains, further confirms the earlier conclusion. Ancient patterns of climate and ocean current circulation depend in part on the distribution of ancient geological features, many of which may be related to the dynamic behavior of the ocean basins. You can imagine, for example, the profound influence which the presence of the Mid-Atlantic Ridge and the East-Pacific Rise exert on the total oceanologic environment of the Atlantic and the Pacific Oceans respectively.

Studies by the Danish Greenland expeditions of the past 15 or 20 years (Haller, oral communication, and manuscript in press, 1966) indicate that lying between Greenland, Norway, and the British Isles there was a land mass which within the past 100 million years has collapsed. The only land mass in that great oceanic area at present is the volcanic island of Iceland. Thus, it is clear that great changes in climate, in ocean circulation patterns, and even in the nature of deposition have resulted from the collapse of this former major land barrier between the Atlantic and the Arctic Basins.

To the degree that we understand modern earth science processes, especially those operating in and about the oceans--to that extent can we unravel the long and complicated history of the Earth as a whole.

The Title III Planning Grant for an Oceanographic Education Center in Falmouth, Massachusetts

Harry S. Merson

The Falmouth Public Schools have been awarded a Federal Grant under Title III to plan an Oceanographic Education Center. For us this is an exciting assignment to which the special resources of the Falmouth community may be applied.

This community, as you have observed, is dedicated to science--to the posing of questions, the proposing and testing of answers, the seeking of insights concerning man and his environment, particularly the sea. Here for this purpose are assembled a nearly unique combination of persons and place. And yet, their presence has had too little effect upon the teaching of science in the schools.

Study of the ocean, which covers more than 70% of the earth's surface, occupies only a minor part in the school's emerging earth science programs. The purpose of this planning project is to change this, and the following excerpts from the application suggest the process: This grant will fund the survey and evaluation of existing educational programs associated with aquariums, planetariums, and museums in order to design a model educational center associated with an oceanarium.

The Oceanographic Education Center, when finally designed with the help of the Advisory Board and other consultants, will be an interpretative center for the science of oceanography for more people than those in Falmouth. Teachers, pupils and adults throughout Southeastern Massachusetts could take trips to the center to understand the oceans' vital resources.

A pilot project of in-service training will create an opportunity for a few public school teachers to become involved in scientific reasoning and investigation under the guidance of a few professional scientists. This teacher's involvement with the scientific method will be interpreted for a small group of students through the design of a teaching unit. Teaching materials including display cases, audio-visual aids, and booklets centered around the topic of the teaching unit will be prepared in conjunction with the unit. Teachers will have the help of a professional museum curator from the Cape Cod Museum of Natural History, and a children's author from the Audubon Society in preparing these exemplary materials.

More thorough knowledge of our own earth is growing as important as knowledge of outer space has grown. For many years scientists had no concept of the many practical values not yet explored in our oceans. Woods Hole, Massachusetts, is one of the few oceanography centers and is considered by many to be the finest facility of its kind in the world. For Woods Hole scientists to inspire others in this important field, the public should become aware of the exciting discoveries now in process. Educators should introduce simplified concepts into the classrooms and children should be able to visit an interpretative center to examine many displays that are not possible in the regular classroom.

Scientific investigation must become a tool of the modern student but can only be taught when it is understood and used by the teacher. Scientists in Woods Hole, many of whom are parents of children in the public schools, are sincerely interested in working closely with Falmouth teachers to help improve the schools' science curriculum and teaching methodology.

An early awareness of man's relation to his environment can lead to an understanding of the need for conservation. The present offerings in the natural sciences are limited in quality and quantity and must be expanded in order to create awareness. The exposure of children from many towns to the Oceanographic Education Center can uncover the great values of the previously unknown oceans.

Attractive display cases, creative audio-visual aids, and informative booklets for school youngsters are lacking in oceanography and many other areas of earth science. They should be developed by this project. These materials should be prepared with professional guidance and include the authoritative data by the professional scientists in Woods Hole which have never before been made available at the elementary and secondary school levels.

One of the aims of this grant is to provide school teachers with an opportunity to become trained in the application of the scientific method of observation and investigation. The in-service training of the teacher will not be the usual type, of course, but will involve a one-to-one tutorial relationship with a professional scientist to investigate an earth-science problem. The teacher's scientific research is then interpreted for use with students through the design of a short course. Display materials, audio-visual aids, and booklets are prepared to correlate with the teaching unit. The fine quality of professional guidance in the preparation of these materials should allow them to become effective curriculum guides for the inexperienced teacher.

The pilot project is to be under the auspices of the center even in its planning stage. This should provide the innovative situation of having initial planning thoughts worked out by highly trained specialists.

Editorial Note. The Oceanographic Education Center in Falmouth is now in operation under the direction of Mr. James Kinney who should be contacted for current information.

Oceanography, Earth Science and the Teacher Crisis

Dr. Robert C. Stephenson

Man has always been fascinated by the sea. We describe the sea as mysterious, as restless and as cruel. In the spirit of high adventure, men through the ages have explored the oceans. The oceans, which cover nearly three-quarters of the earth's surface, represent a vast frontier to be conquered. When people get excited about oceanography--the application of science to the study of the oceans--it is not always clear whether they are moved by the spirit of adventure or the spirit of true scientific inquiry.

As our civilization is currently developing, we are increasingly dependent on both land and sea for food, raw materials, energy, and as a media for transportation. It is important that children begin early in their formal education to add to their knowledge about man's natural environment--the solid earth, the atmosphere and the oceans. It is logical, therefore, that concepts and phenomena relating to the oceans be introduced at various levels in elementary and secondary school science curricula.

Oceanography is not a narrowly defined area of science. It is indeed a complex assemblage of many sciences oriented toward a study of the earth's oceans. Oceanography is rooted in fundamental mathematics, physics and chemistry. It is an integral part of earth science which is the study of the system earth and its environs in space. It is impossible to study the oceans without considering the interrelationships between the oceans and the solid earth--the realm of geology. The dynamic mixing of the oceans and the atmosphere accounts for the close linkage between oceanography and atmospheric science or meteorology. The merging of oceanography and biology is obvious when one considers the abundance of life in many forms inhabiting the sea. Man's efforts to conquer the restless, cruel sea has challenged the best of engineering and technology.

Teaching science, in the modern sense, is not a process of communicating an encyclopedic mass of information. Modern science teaching seeks to develop science as inquiry, drawing on man's innate curiosity. Oceanography is the science inquiring into the concepts and phenomena of the oceans and the interfaces of the oceans with the solid earth and the atmosphere. To adequately teach the principles of oceanography at the secondary school level or even the elementary school level requires that the teacher have at least minimal college preparation in oceanography or earth science. Herein lies a problem.

There are very few colleges and universities which offer curricula in oceanography. There has been a widespread opinion among oceanographers that undergraduate curricula in oceanography should be discouraged rather than encouraged. They have envisioned oceanography as an area for graduate study and research which should attract scientists trained in the basic disciplines of science. This view is reflected in the ratio of undergraduate to graduate departments in oceanography in our colleges and universities. The Interagency Committee on Oceanography (1965) reported on 21 institutions offering an undergraduate major in oceanography in the academic year 1965-66, while 41 institutions offered training at the master's level and 31 at the Ph.D. level. Single courses or a sequence of one or two courses in oceanography may be taught in a number of colleges and universities but more often than not by a faculty member who has had little or no formal training or experience in the field. Course offerings in marine biology are more widespread than those in physical oceanography and marine geology. Since so few colleges offer adequate undergraduate training in oceanography it is not possible for most teachers preparing to teach this subject in elementary or secondary schools to obtain adequate pre-service preparation. Furthermore, since most graduate level training in oceanography requires rigorous prerequisites in the basic sciences and mathematics, the elementary or secondary school teacher desiring to pursue graduate study in oceanography is likely to find these requirements difficult.

The most popular scheme for incorporating oceanography into elementary and secondary school science curricula is as a component part of earth science. New York State started the trend in the early fifties with the introduction of each science in the secondary school science curriculum. Subsequently schools in Pennsylvania and New Jersey followed by introducing ninth-grade science courses around 1960. The trend rapidly gained momentum throughout the country so that by 1965 an estimated 621,000 secondary school students, principally 9th graders, were taking a course in earth science (ESCP Newsletter, January, 1966). Significant in the nationwide adoption of earth science courses has been the impetus resulting from the organization in 1963 of the Earth Science Curriculum Project (ESCP) under the auspices of the American Geological Institute with financial support from the National Science Foundation. ESCP has produced a text, Investigating the Earth, a laboratory manual and a teacher's guide which have undergone two years of testing in selected secondary schools and revision for formal publication by the Houghton Mifflin Company in 1967.

Teacher preparation has been a matter of grave concern to those responsible for direction of the Earth Science Curriculum Project. It is recognized that no matter how excellent the ESCP course materials may be, the successful adoption of Investigating the Earth will depend in large measure on the subject matter preparation of the earth science teacher using the materials. In 1965 ESCP inquired into the background of teachers then teaching earth science. The analysis of the college preparation of 2556 earth science teachers responding to this survey were reported in the ESCP Newsletter, January, 1966. It is evident from the survey that most of the teachers currently teaching earth science have much less than adequate preparation in the earth science disciplines and most have only minimal preparation in the basic sciences. Of the responding earth science teachers, 89 per cent reported no college course work at all in oceanography, 10 per cent reported 1 to 6 semester hours of oceanography, and 1 per cent reported 7 to 12 semester hours.

ESCP has devoted considerable attention to forecasting earth science enrollments and earth science teacher demands. The ESCP (ESCP Newsletter, January, 1966) projection assumes that one-third of all ninth graders may be expected to be taking earth science by 1970 in which case approximately 19,500 qualified earth science teachers would be required to meet the classroom needs of the projected 1,710,000 earth science enrollment. The tremendous increase in the number of earth science teachers likely to be required by 1970 when viewed in light of the findings of the investigation into the preparation of present earth science teachers focuses attention on an obvious need for a massive teacher preparation effort.

The studies of teacher demand by the Earth Science Curriculum Project reveal the need for large scale in-service teacher preparation programs as a means of up-grading the earth science subject matter background of teachers being pressed into service to teach earth science courses without adequate preparation. An estimated 3,300 teachers were teaching earth science in 1965 with less than minimal academic preparation for such an assignment. By 1970 this number of less than adequately prepared teachers could rise to nearly 10,000.

The principal efforts to provide earth science background for teachers already in service have been through National Science Foundation supported summer institutes. Considering the number of earth science teachers with inadequate training, the opportunities afforded for summer institute participation are much too limited. These opportunities appear even more inadequate when one realizes that in most instances three successive summer institutes are necessary to cover the broad field of earth science with its several major disciplines - astronomy, geology, meteorlogy and oceanography. In addition to the NSF summer institutes there have been a few academic year institutes offered by various institutions. Some in-service institutes have been conducted locally. The most fortunate earth science teachers are those teaching in the ESCP test program, for they have benefitted from a concentrated orientation program before starting with the ESCP materials and also weekly contacts with the ESCP test center. The teachers associated with these test centers have been able to discuss the course materials and their teaching problems with fellow teachers and with a college consultant participating in the center.

Unfortunately,most summer, academic year and in-service institutes are staged using "off-the-shelf" courses in geology, astronomy, meteorology, etc. These courses are usually descriptive in content; they usually do not attempt to integrate the study of earth processes and materials. Often it takes a formidable number of credit hours in various courses relating to earth science to provide adequate coverage of the field.

In the specific area of oceanography there is little available in the way of assisting programs for science teachers who wish to raise their subject matter competence. Only one institution has offered a summer institute in oceanography. Some earth science institutes do include limited treatment of oceanography. With so few colleges offering undergraduate oceanography, the opportunities for course work in the field will continue to be limited.

In summary it appears that demands for earth science teachers and for teachers of ocean science materials will far outstrip our abilities to prepare teachers either by pre-service or in-service programs. Colleges and universities, bound by discipline-oriented traditions and conservatism, have not responded aggressively to the requirements for programs to prepare teachers to teach modern earth science. The National Science Foundation has invested substantially in the Earth Science Curriculum Project efforts to develop an investigative earth science text with laboratory manual and teacher's guide. Neither the National Science Foundation nor the U. S. Office of Education, however, give indication that they understand the magnitude or complexity of the earth science teacher preparation problem. Earth science as a secondary school science course could have a rather short and disastrous life if a majority of the teachers are incapable of handling the new earth science materials. Such a failure would be ironic at a time when national interests are focused as never before on oceanography, atmospheric sciences, pollution control and other areas of environmental sciences.

The problem of providing adequate numbers of earth science teachers with reasonably adequate subject matter preparation will require a very substantial infusion of money, time, effort, enthusiasm and dedication. Money must be made available to college faculty in a number of institutions to provide release time and support needed to produce new college courses and course sequences which will unify the earth sciences as an investigative science. Such support may be especially appropriate for carefully screened emerging institutions which have the talent and capacity for such innovation. New audio-visual and tele-communications techniques should be exploited to the fullest for reaching classroom earth science teachers with in-service instruction. Special programs to improve pre-service and in-service laboratory experiences of earth science teachers must be undertaken. Obviously there must be an adequate and continuing investment in support of faculty engaged in putting these new college course materials and teacher preparation techniques to work if the effort is to be most effective. There must also be ample opportunities, commensurate with the demands, for pre-service and in-service earth science teachers to benefit from these efforts.

Oceanography, atmospheric sciences, astronomy, geology - the whole family of earth sciences-have a real place in the subject matter covered in elementary and secondary school science curricula especially if we feel a responsibility to educate individuals to understand something of their environment on planet Earth. Our success in achieving this objective will depend on how vigorous we are in our earth science teacher preparation efforts.

The Training of Oceanographers, Ocean Engineers, and Ocean Technologists

Dr. John A. Knauss

From the speakers who have addressed you earlier today, I believe you have some idea of the broad field of oceanography, and it is a very broad field. As you might guess, formal education in oceanography presents some real problems and challenges. To begin with, not everyone is agreed on the bounds of the discipline. Oceanography is not a single science but the application of many sciences to the problems of the ocean. Oceanography is probably not the proper name. The purists are correct; we should call the field oceanology and not oceanography. After all, the study of life is biology and not biography . Presumably, a similar argument can be made for oceanology.

Regardless of the name we give to the subject, the real question is how do you train people in this field? There are still many who feel there really is no such discipline as oceanography. They would grant that perhaps a course or two might be useful, but that a whole curriculum in oceanography would be a mistake; that a research scientist working on problems in the ocean would come better equipped with a degree in chemistry, biology, mathematics, or even physics. Our host institution, the Woods Hole Oceanographic Institution, is an excellent example of a very vital and viable organization that has gotten along very well for many years without very many trained oceanographers on its staff. There are relatively few people at Woods Hole who received their degree in oceanography or, in fact, have had any formal oceanographic training. This morning I was having a cup of coffee with a few of my friends on the staff here, and, thinking about this talk, I asked them what field they had specialized in in college. One was genetics, a second was physics and the third, believe it or not, was forestry. As you can see, you don't really need formal training in oceanography to succeed in this business. On the other hand, I would like to point out something that probably couldn't have happened fifteen years ago. Of the three speakers we have heard today, all have had some oceanographic training. One of them has his Ph.D. in oceanography and the other two studied with oceanographers.

Formal oceanographic training has been until recently, and still is, primarily a graduate curriculum, and I think if I describe our curriculum at the University of Rhode Island I will at the same time be giving an adequate description of at least two-thirds of the oceanographic curricula in this country. All have evolved from the first such curriculum of this nature, that of the Scripps Institution of Oceanography. At URI we accept students for graduate study who have a bachelor's degree in any field of science or engineering. They can have majors in biology, physics, chemistry, geology, mathematics, electrical engineering, etc. They come with various backgrounds and we provide them with a program tailored to their needs. We have very few requirements which are common to all of our students. One requirement is a series of four core courses in physical, chemical, biological and geological oceanography. The prerequisites for these courses are not very stringent.

To take our beginning course in biological oceanography a student need only have had an undergraduate course in biology sometime in his career. For the course in physical oceanography he needs to know a little freshman physics and some calculus. The same kinds of prerequisites apply to our courses in chemical and geological oceanography. Although the prerequisites are limited, you might be surprised at how many biologists, at least until recently, would arrive without having studied calculus, and, of course, no proper physicist has ever had a course in biology. As a result, many of our prospective students must make up one or more of these courses after they arrive.

Because the prerequisites are not very difficult, the level of sophistication of these four basic courses cannot be very high, at least by graduate level standards. However, many of our biology students sweat blood over their course in physical oceanography and vice versa.

The other requirement common to all of our students is a student-run weekly seminar in which all of our students must participate during the time they are in residence. At this seminar, second year students and beyond discuss their research. This means that physical oceanographers must sit through week after week of listening to other students talk about problems in zooplankton, population dynamics, etc., and that biological oceanographers must watch differential equations being written on the board. I know of no better way to drive home the far-ranging interdisciplinary approach to oceanography than by such seminars. Hopefully, when a student graduates he leaves with some real feeling of what others are doing in the field of oceanography; and also hopefully he will carry with him throughout his active career this interdisciplinary approach to the problems of oceanography.

Except for the seminar and the four core courses, the student's program is developed with the help of his advisor to fulfill his own needs and interests. A prospective biological oceanographer will learn more about the biological problems in the ocean but, at the same time, he will learn more classic biology in such fields as genetics, physiology, molecular biology, etc. This program is easy to describe but difficult to practice. The problem of how one thoroughly trains a person in his basic discipline of physics, chemistry or biology and at the same time provides him with sufficient understanding of the oceans is a problem with no simple solution.

Allowing for local variations, the program which I have described at the University of Rhode Island is similar to the one in practice at the University of Washington, Oregon State, Scripps Institution of Oceanography and the University of Miami; in fact, at most of the schools where a broad program covering all aspects of oceanography is provided. There are now something like fifty-three colleges and universities in the country which provide some training in oceanography. There are about thirteen colleges or universities in this country which give Ph.D.'s in "Oceanography." Except for those with the very large programs such as I have just mentioned nearly all the rest stress one aspect or another of oceanography, i.e., they specialize more or less in biological oceanography, physical oceanography, some combination of physical oceanography and meteorology, etc.

Recognizing the interdisciplinary aspect of oceanography, some colleges run their program with a committee rather than by establishing a separate department. A student can study oceanography at Harvard although there is no Department of Oceanography listed in the catalogue. The program is run by a committee representing different departments and faculties within the university. At Yale, at least until very recently, oceanography was strongly represented in the Biology Department and the students who wanted to be biological oceanographers could do so through that department.

There is very little opportunity to major in oceanography at the undergraduate level. The largest, and until recently, the only undergraduate program was that of the University of Washington. This program was established in the early 1950's. It can be characterized as a very strong general science curriculum, oriented toward the oceans. Even here students become biologically or physically oriented at the undergraduate level. Recently at least three other schools have begun to give undergraduate programs in oceanography. At New York University and the University of Michigan the training has been combined with meteorology in a department of oceanography and meteorology. At Humboldt State College in California, you can now get an undergraduate degree in oceanography under their Division of Natural Resources.

Most oceanographers, including myself, have long believed that undergraduate training in oceanography is a mistake. If you are going to be a scientist you need a strong background in the basic sciences before you begin the study of the oceans. Although this argument may still be valid when it comes to training Ph.D.'s in oceanography, I am no longer so certain that undergraduate training in this field is a mistake. I am also quite sure that what I think isn't going to make very much difference. I suspect we are going to see a large increase in the number of undergraduate curricula in oceanography. The success of the University of Washington's program, at least in terms of their ability to place their graduates, seems to speak well for at least a few more such programs in the future. There is going to be an ever-increasing need for people trained in the marine sciences and I think there is an increasing need for these people at all levels of education. I also suspect there is considerable room for experimentation in undergraduate curricula in oceanography, but I confess I don't have any very useful ideas on this subject.

Ocean engineering is a new and exciting field, or perhaps it's an old and traditional field which has been given an exciting new name. At any rate, more and more students are going to school to study ocean engineering. The problem of training an ocean engineer is, I think, even more difficult than training an oceanographer. What kind of engineering training is required to develop the instrumentation and data analysis concepts which Dr. Fofonoff was speaking about earlier? He needs someone with training in electronics, mechanical engineering, naval architecture, communication theory, etc. How do you train a person who is competent in all of these disciplines? You don't. Probably the best you can do is to train people in the classical fields of engineering who know something about the oceans. At least that is what our graduate curriculum in ocean engineering is at URI. A student continues to earn his degree in electrical engineering, mechanical engineering or civil engineering with what amounts to a minor in oceanography. We require masters' theses as well as a Ph.D. dissertation. A student in ocean engineering will do his thesis on some topic of ocean technology, marine science or marine technology, and at least one of the faculty from the Graduate School of Oceanography will serve on his committee.

I think the problem of training ocean engineers is even more difficult than that of training oceanographers. At present engineering departments all over the country are attempting to revise their curricula so that the engineering graduate will not be faced with technical obsolescence at the end of five or ten years because of the rapid strides which are being made in engineering. You must somehow teach students about the principles of communication theory whether it is applied to the problems of the ocean or to the problems of space or to the problems of the communication industry. One should not worry too much about whether this is called ocean engineering, space engineering or some other kind of engineering. There are certain fundamental fields of knowledge which an engineer must be expected to master.

Perhaps the idea of setting up a separate department of ocean engineering does not make very much sense. In an ocean engineering department you would presumably have people who study pollution, naval architecture, beach erosion, problems of electronic instrumentation, design of structures of various kinds. Thus, ocean engineering must be a very broadly based interdisciplinary field of engineering. However, regardless of the logic, I suspect there is going to be an increasing number of departments of ocean engineering. In fact, we expect to have one at the University of Rhode Island. The arguments for departments of ocean engineering are more interwoven with the traditional ways in which things are done in a university than any internal logic concerning the discipline of ocean engineering. Hopefully, these new departments of ocean engineering will provide interdisciplinary training. The three or four curricula presently being offered at universities with ocean engineering programs are similar to that at the University of Rhode Island. A student spends most of his time taking traditional engineering courses. He also takes a few courses in oceanography to learn something about the oceans. In addition there may be one "state of the art" survey course in ocean engineering problems.

Florida Atlantic is the only university that I know of where you can get an undergraduate degree in ocean engineering, and although they list a large number of ocean engineering courses in their catalogue it is quite clear that these same courses might also be called thermodynamics, fluid mechanics, circuit theory, etc., and could be given in departments of mechanical engineering or electrical engineering.

I think colleges and universities are wise to develop curricula in ocean engineering. In my opinion, I think this field is going to grow very rapidly in the next ten or fifteen years. I believe it is a field with a very excellent future, perhaps an even better future during this next decade than oceanography.

Having first said something about the training of oceanographers, which I should know something about, but about which I feel very humble; and then the field of ocean engineering, a subject of which I am certainly not an expert, but one in which I have been forced to do a bit of thinking in recent months because of problems at our own university, I now come to an area where I have very little experience and relatively little insight into the educational problems -- namely, the two-and four-year terminal programs in training ocean technologists of one kind or another. There are a few such programs available. We have one in Maine. The Southern Maine Vocational Institute has a two-year program in marine technology. The Maritime Academy at New York has a four-year program of a similar nature. In 1967 at the University of Rhode Island we expect to start a two-year program in fisheries and marine technology. It will be an associate degree prog am.

Most of the specialized programs that I am aware of are related in some way to sea-going activities. I believe there is a limited but growing need for persons with this kind of training - for trained fishermen, for persons who work at sea but are not a part of the traditional ship operating crews, and I suspect that under the new Vocational Training Act that again this will be an area in which there is certain to be growth in the near future.

However, you do not have to study in such a program to work in this field. As I've said before, there are many scientists who study the oceans who did not get their Ph.D.'s in oceanography. Certainly, most of today's ocean engineers did not get their training in ocean engineering. I am fairly certain this condition will continue to hold even though more and more universities provide formal programs in oceanography and ocean engineering. I am positive that this will be the case at the technician level. For instance, if you were to go through the laboratory here at Woods Hole and ask the girls and young men who are working as technicians "what kind of training do you have?" you would find that they would have bachelor's degrees in biology, chemistry, electrical engineering, etc. In other words, they would have had their training in the more traditional fields of science and engineering. As such, they would be perfectly capable of going to work in any kind of laboratory, oceanographic or otherwise. I don't think this condition is going to change. I don't think it should.

I suspect that one of the reasons why there are so many of you here today is that all of you sense that marine science and technology are going to grow in this country and are going to grow very rapidly. I think it is clear that New England's position in this field is also going to grow. How fast it grows remains to be seen. I've talked with several groups recently about the growth of the marine sciences and about the sea-grant colleges, a program in which I am very much involved, and the question continually comes up as to what growth rate we can expect. I would like to close on a note of caution at least over the short range. In a fast growing field such as this I think we tend to overestimate the rate at which things will happen. We almost always overestimate over the short term -- over a two-year period and perhaps even a four-or five-year period. However, I think, with very few exceptions, all of us underestimate perhaps by as much as one or two orders of magnitude the amount of change we will see in a fifty-year period. I suspect that in the next twenty years the amount of progress in the marine science and technology will be greater than any of us in this room have estimated.

CHAPTER IV

PANEL DISCUSSIONS AND RECOMMENDATIONS

Following the presentations by the speakers, six concurrent panels were convened. It was the task of each of these panels to discuss the place of ocean science education in the school curriculum, the levels at which ocean science concepts can effectively be taught, the problems of introducing new materials into the curriculum, the availability of suitable textbooks and source materials, and the problems associated with having adequately prepared teachers who can teach ocean science. Each panel consisted of four to six members who led the discussions. All of the rest of the participants at the conference were assigned in approximately equal groups to attend the panel sessions and contribute to the discussions. Following are summaries of the panel discussions.

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PANEL 1

Mr. Ralph Keirstead, CHAIRMAN
State Consultant in Science Education
Connecticut Department of Education
Hartford, Connecticut

Mr. Harold Mahoney
Director, Division of Instruction
Connecticut Department of Education
Hartford, Connecticut

Mr. John Arena
Science Teacher
Valhalla School District No. 5
Valhalla, New York

Mr. Thomas P. O'Connor, RECORDER
Senior Supervisor in Education (Science), Massachusetts Department of Education
Boston, Massachusetts

Mr. Joseph E. Killory
Assistant Director, Bureau of Elementary and Secondary Education
Massachusetts Department of Education
Boston, Massachusetts

Mr. Ralph Keirstead expressed the view that school programs should provide opportunities for study of anything which is important and significant to the society which supports the school programs, but that the school programs do not always support such opportunities. What is important and significant in one era is not necessarily so in the era that follows indicating that school programs should change rather readily. However, school programs tend to resist change and get out of step with the needs of the times. Sometimes a major effort is required to bring about educational change.

Mr. Keirstead pointed out that a major effort has been made during the last ten years to change science education. Large changes have been made in science programs, and the end of change is certainly not in sight. Therefore, it seems that the climate for making ocean science an important aspect of the school science program is favorable. In fact, one can say with some validity that significant steps have already been taken toward bringing ocean science into the school program. Earth science, almost unknown as a high school subject a decade ago, is now a course in the science program of a great many schools. According to Mr. Keirstead, ocean science should be a good-sized segment of an earth science course. In his experience, this is not usually the case, largely because few teachers of earth science are well trained in ocean science. He feels that there is in reality a need for this subject already in many secondary school programs and that the big problem is to put (ocean science) it in the proper place in the curriculum.

In the area of elementary school science, Mr. Keirstead pointed out that a great amount of ferment exists. A number of large curriculum development projects and many more smaller ones are underway. There does not appear to have emerged a pattern for elementary school science which is generally accepted. This being the case, there would seem to be no reason why some aspects of ocean science that seem desirable cannot be incorporated into the school science curriculum.

Mr. Joseph Killory, stated the view that students should be made much more aware of their physical surroundings, including the oceans. He emphasized that putting additional items into the school curriculum requires planning and action. There are many special interests which are seeking increased emphasis in the school program. Decisions must be made as to what may properly be eliminated or reduced in emphasis to provide time for including new areas. State Departments of Education should assume a large role in deciding what should be included in educational programs. Unless responsibility is fixed for making decisions on curriculum matters, the traditional long lag will continue between the emergence of an important area and its inclusion in school programs.

Often, according to Mr. Killory, those who are concerned with important matters, such as ocean science, work in isolation from the schools. Sometimes, curriculum changes result from administrative fiat, even when teachers are not prepared to provide effective instruction in the new areas. Under such circumstances, the new areas are unlikely to prosper. They may even disappear after a brief period. If ocean science is to become a viable part of the instructional program, it would be desirable to alert all those responsible for education to its importance so that support for it can be assured. A sound educational program is more likely when all concerned with it work together in developing it.

Mr. John Arena, Valhalla, New York, discussed an instructional program in oceanography, which he is developing under the Cooperative Research Act. The project calls for the development of an independent study program, involving students from several school districts. The study program will be developed by the director and a group of consultants. Reading lists, laboratory activities and a syllabus will be developed. The independent study plan was chosen to avoid the problems of introducing a new course into an already crowded curriculum. The success of the plan can only be conjectured at present. It may be that special laboratory facilities will be needed as well as space in which students may undertake projects.

Dr. Frank E. Sorenson, Chairman of the Department of Educational Service, Teachers College of the University of Nebraska and a member of the Link Foundation Technical Board, commented on possible ways to up-date and improve educational programs. He suggested that even though laboratories and special equipment are important, the key to change is the teacher. If arrangements could be made for good teachers to work with ocean scientists at laboratories like those of the Woods Hole Oceanographic Institution, they would become enthused and there would be little question that ocean science would appear in school programs. Mr. Sorenson also suggested that the teacher, who is willing to capitalize on the interests of students and to help students organize procedures for learning about matters that interest them, can provide rich experiences for students in areas in which he personally is not deeply trained.

Dr. Ramon E. Bisque, Director, Earth Sciences Curriculum Project, Boulder, Colorado, contended that highly specialized courses such as oceanography in the high school are undesirable, because students might get a fragmented view of science. He felt that there rather should be a stronger emphasis on the basic principles underlying all the sciences. Mr. Killory expressed himself as being of the same opinion as Dr. Bisque in this regard.

PANEL 2

Mr. Wesley A. Hall, CHAIRMAN
Coordinator of Secondary Education
Rhode Island Department of Education
Providence, Rhode Island

Mr. David L. Ramsey
State Supervisor of Science
Florida Department of Education
Tallahassee, Florida

Dr. Thomas E. Moriarty
Professor of Education
University of Rhode Island
Kingston, Rhode Island

Mr. Stewart S. Sargent, RECORDER
Senior Supervisor in Education (Science)
Massachusetts Department of Education
Boston, Massachusetts

Mr. Roger Ming
State Supervisor of Science
New York Department of Education
Albany, New York

Dr. Emanuel Maier
Professor, Earth Sciences Department
State College at Bridgewater
Bridgewater, Massachusetts

Mr. Roger Ming stated that there is a keen interest in earth science in the New York State schools. Probably the study of oceanography in the New York public school system will be restricted to the part oceanography plays in the earth science curriculum. They are about to revise the State course of study in earth science. They are also planning to try the Earth Science Curriculum Project materials.

Mr. David L. Ramsey spoke about ocean science education activities in Florida, a State which has 1,800 miles of shoreline and in which no student is more than 1 1/2 hours by automobile from the ocean. More students are looking for additional science studies at the 12th grade level. Demands for courses in marine biology and oceanography are becoming greater. Last December teachers of marine biology, oceanography, and earth science met with a group of science educators and scientists to explore what needed to be done to meet this demand. Many of those present at this meeting felt that nothing new was needed at the secondary level or at the undergraduate level, and that the study of oceanography should be reserved for the graduate schools. At another meeting, that of the Florida Oceanographic Society, grouping was the first phase in an effort to produce field and laboratory experience in marine biology. The teacher should have resource materials relating to his course in science, the elementary school or in the secondary school. The teacher should attempt to involve the local environment as much as possible. Mr. Ramsey explained that efforts so far have been concentrated on encouraging teachers to develop a course of study. At the present time, there are nine teachers offering marine biology or oceanography to almost 500 students. The aim of the Florida Department of Education is to produce a package of materials which can be used by other counties on the shoreline.

Mr. Stewart S. Sargent reported hearing about a joint planning grant that has been received by 12 Massachusetts school districts which border the south shore from Plymouth to Hull. An oceanographic curriculum is to be developed as part of a total science curriculum. The City of Boston is in the process of building an aquarium on the waterfront. A curriculum is also being developed to be used with the aquarium exhibits.

Dr. Thomas E. Moriarty spoke of the glamour associated with oceanology. He felt the intermediate grades lent themselves best to the introduction of an interdisciplinary approach.

Dr. Emanuel Maier explained about the interdisciplinary approach to earth science being utilized at the State College at Bridgewater, Mass. He expressed need for additional funds to implement this approach.

The Children's Science School at Woods Hole, Massachusetts, and the Brewster Museum summer program on Cape Cod were cited as examples of excellent summer programs involving oceanography.

The following recommendations were made as a result of the discussions:

1. Steps should be taken to produce a curriculum guide and/or a resource guide for ocean science. A preference for an interdisciplinary approach was expressed.

2. Teacher training programs should predate any curriculum implementation in oceanography. A three-year sequential policy of training was recommended for teachers who are to teach ocean science.

3. A State Department of Education specialist in ocean science education should assist teachers at the elementary as well as at the secondary school levels.

4. Effort should be made to disseminate new information about ocean science education as it becomes available.

5. A traveling lecturer program in oceanography with portable demonstration units should be available to schools.

6. The discovery approach should be emphasized and the descriptive approach to oceanography should be avoided as much as possible.

PANEL 3

Mr. John W. Packard, CHAIRMAN
Senior Supervisor of Science
Massachusetts Department of Education
Boston, Massachusetts

Mr. Robert D. Binger, RECORDER
Supervisor of Science
Florida Department of Education
Tallahasee, Florida

Mr. Harry S. Merson
Superintendent, The Public Schools
Falmouth, Massachusetts

Mr. Hugh Templeton
Chief, Bureau of Science Education
New York Department of Education
Albany, New York

Mr. Packard opened the discussion by pointing out that we were living in an age of ferment, in science and in education. The demands of an age which has opened up vast new frontiers are reflected in a re-examination of our course content and methods of teaching. There is need to consider carefully programs which will have meaning and significance for the children of this new era. There seem to be many indications that a study of the oceans has much to offer in motivating today's students. The oceans are one of today's frontiers, rich in promise, essential to our economic welfare, and vital to our national security.

Mr. Packard expressed the view that children in any grade have the intellectual capacity to cope with new concepts, provided that the teaching of these concepts is adjusted to the grade levels and backgrounds of the children. He felt that many of the basic ideas of science which have been unnecessarily delayed in the past can be taught meaningfully at an earlier age. He called student involvement the backbone of our new science programs. The study of the oceans provides a wealth of opportunity for student involvement at all levels.

Mr. Harry S. Merson, Superintendent of Public Schools, Falmouth, Mass., emphasized the need for preparation of competent teachers with particular competence in ocean science. Under Title III of the Elementary and Secondary Education Act of 1965, the Falmouth Public Schools are establishing a center for ocean science education which will stress the preparation of teaching materials and enrichment for science teachers in the area.

Mr. Hugh Templeton reviewed the program of instruction in earth science in New York State which has pioneered in this area and where enrollment is widespread. He spoke highly of its success and indicated that the Earth Science Curriculum Project is being studied by Mr. Roger Ming of the New York State Department of Education with a view to the inclusion of all desirable oceanography material in the State syllabus. He stressed interest of the New York State Department of Education in the outcome of this conference.

Mr. Robert D. Binger expressed the interest of the State of Florida in the objectives of this conference. He pointed out that Florida had a unique concern with the oceans and an unexcelled opportunity to make oceanography and marine biology a vital part of their course offering. He summarized the activities of a number of Florida schools. Among those were Jacksonville Beach, Melbourne, Stuart, Barton County, Miami Beach, Sarasota, Riverview, and Citrus County.

Mr. Binger stated that Florida had followed the lead of New York and Pennsylvania in developing earth science programs and was reviewing the Earth Science Curriculum Project materials. He reported on a State conference which had considered programs relative to oceanography and marine science. This conference led to the appointment of an Environmental Sciences Committee of which he is chairman. The committee plans to develop a proposal for a planning grant under which they would consid.r methods of improved teacher training, followed by a set of guidelines for people at the local level to help them prepare their own programs in the field of the ocean sciences. They also would plan a supplement for biology text books.

The following conclusions and recommendations were agreed to:

1. Oceanography is interesting, exciting, growing at a fast pace, and vital to national security and economic progress.

2. Ocean science should be studied in elementary and secondary schools. The content should be appropriate to the needs, interests, and grade levels of students and should be compatible with the methods and philosophy of modern curriculum studies.

3. The preparation of curricula, textbooks and supplementary materials is just beginning, but the need is recognized nationally.

4. Teachers knowledgeable in ocean science are in short supply. Teacher preparation institutions are urged to recognize this situation.

PANEL 4

Mr. Howard I. Wagner, CHAIRMAN
Consultant, Science Education
New Hampshire Department of Education
Concord, New Hampshire

Dr. Eugene Allmendinger
Coordinator, Marine Affairs
University of New Hampshire
Durham, New Hampshire

Mr. George M. Strout
Director, New Hampshire Technical Institute
Concord, New Hampshire

Mr. Charles Peck, Jr., RECORDER
Science Teacher
North Hampton Elementary School
North Hampton, New Hampshire

Mr. Richard Carle
Educational Consultant for the Seacoast Regional Plan
Sanders Associates
Nashua, New Hampshire

Mr. David Staples
Instructor in Oceanography
Phillips Exeter Academy
Exeter, New Hampshire

Mr. Wagner led off the panel's deliberations by discussing the place of oceanography in the science curriculum. He said that there is a place for every approach which capitalizes on motivation and results in a better understanding of science. The key is relevance. A course or course units in ocean science have special appeal to students who live in regions near the sea coast. He felt ocean science units would complement present elementary school curriculum development work and would enrich the ocean science portion of secondary school earth science courses. He said that there was further need for development of an entire course in ocean science for secondary schools, similar to the year course at Phillips Exeter Academy, Exeter, New Hampshire. One of the main difficulties encountered in teaching ocean science at the present time is the lack of availability of suitable resource materials.

Mr. Wagner said that, for the most part, present science teachers are not prepared to teach ocean science. Training programs are needed, but one of the problems has been not knowing exactly what preparation is suitable. It is time, he felt, for committees of oceanographers and science education specialists to get together and develop such a program.

Following are some topics which Mr. Wagner suggested would make valuable resource aids and/or units:

a. Man living-in-the-sea
b. Wresting chemicals from the sea
c. Sea-farming
d. The menace of sea pollution
e. Shallow and deep currents affecting the New England coast
f. Conversion of sea water into fresh water
g. Tidal ecology
h. The New England fishing industry
i. Project Mohole
j. The science of waves
k. Topography of the floor of the Atlantic Ocean
l. Underwater photography
m. Comparison of the U.S. and the U.S.S.R. efforts in oceanography

Dr. Eugene Allmendinger stated that the great debate at the present time is whether or not the study of oceanography should commence at the undergraduate level or continue only, except for a very few institutions, at the graduate school level. He said that at least a survey course in oceanography should be available for undergraduates. He described the oceans as our new frontier on earth, with the world's continental shelves being equal in area to the entire land area of Africa. He indicated that the University of New Hampshire was planning to design a scientific sea laboratory.

Mr. George M. Strout said that a recent survey of technician needs and training for oceanography revealed the same picture as previously revealed for nuclear and space endeavors; namely, technicians who are well trained in basic sciences and engineering skills. Industry and laboratories can give specialized training later. However, technical institute facilities can help prepare students better by introducing problems and situations applicable to the sea.

Mr. David H. Staples asserted that the study of oceanography is appropriate in the secondary school because it is a good stimulant and maintains a student's interest in science, introduces new information, and aids in destroying the stereotype of the scientist. He described the course he teaches at Phillips Exeter Academy, which meets two hours a week throughout the year. He said that the interdisciplinary aspect of oceanography lends itself well to a team-teaching approach involving physicists, chemists, biologists, geologists, and other specialists. Good laboratory and field work is essential to student involvement. Phillips Exeter Academy has purchased a boat and has made good use of much homemade equipment. A major problem is that of finding a textbook that is sufficiently elementary for the secondary school level.

Mr. Richard Carle spoke about the need for a citizenry informed about oceanography. He said that the needs of industry in the oceanographic field are increasing at a fast rate and in all dimensions, and new unknown ones are to come. Industry recognizes that tremendous growth in oceanography is upon us, and it equally recognizes that progress in this burgeoning field rests upon an informed citizenry and a supply of suitably trained manpower.

Mr. Andrew F. Collahan, Hull School, Hull, Massachusetts, told about the summer program he is presently directing and which he is hoping to incorporate in the regular school year offering. Mr. Ernest E. Roney, Jr., Museum of Science, Boston, Massachusetts, reported that oceanography is an important part of their summer workshop program for teachers who teach grades one through eight.

PANEL 5

Mr. Evan Sweetser, CHAIRMAN
Consultant in Science and Mathematics
Vermont Department of Education
Montpelier, Vermont

Mr. Lawrence W. Latour, RECORDER
Senior Supervisor in Education (Geography)
Massachusetts Department of Education
Boston, Massachusetts

Mr. Robert Mills
Science Teacher
Putney School
Putney, Vermont

Miss Wilma Shields
Science Teacher
North Quincy High School
Quincy, Massachusetts

Mr. William Hilliard
Coordinator of Mathematics and Science
Citrus County
Inverness, Florida

Mr. William Hilliard said that Citrus County on the west coast of Florida had received a grant under Title III of the Elementary and Secondary Education Act of 1965 for the purpose of planning a marine science station. Six counties, two junior colleges, the State Board of Education and the State Board of Conservation are cooperating in planning the project which will include a marine aquarium. The facility, which will be located so as to be not more than 50 miles from any school in the six counties will be a station at which marine organisms can be obtained for study in the schools and colleges. It will also be a field day center in addition to serving as a location for summer programs. Part of the area in which the station will be located will be left in its natural state for field trip purposes. Fresh water conservation will also be studied at the station.

Mr. Robert Mills stated that although Vermont is a land-locked State, schools in Vermont still have an interest in ocean science. There is interest at Putney School in teaching a good introductory biology course using the experimental approach. They believe that biology should be an environmental type of study using living organisms. The school owns a thousand acres with three ponds. The techniques of the study of the ponds is similar to the study of oceanography in many respects. The students make plankton collections and study the fluctuations in numbers of plankton in the ponds. This kind of study excites them because they see the dynamics of living things.

The Putney School conducts ten days of a project period at the end of each term. The student selects the topic of interest to him and studies only that project for ten days. A select group of the biology students go to an island off the coast of Maine for ten days where they camp and study the marine environment. They study tidal pools, and they collect and study marine organisms. The students use their own ingenuity in their study under the general guidance of two teachers. Another group of students recently went to the Bahamas during part of their three weeks' Christmas vacation to study the marine environment there.

Miss Wilma Shields reported that her school has a marine science class that meets after school, thus making it possible to take field trips without interfering with regular classes. Individual research is encouraged. Some of the students in this class assist elementary teachers on field trips, and report on their research projects in a simple way. Other teachers cooperate in this marine class. When the class studies the chemical aspects, they go to the chemistry classroom, and the chemistry teacher teaches the related results. When the class studies waves and physical phenomena they go to the physics teacher. During one project the students worked on seeding a clam bed with the cooperation of the State Conservation Department. Miss Shields feels that it is desirable for a larger school to have an aquarium where students can see some marine organisms first-hand.

PANEL 6

Mr. Donald W. Robinson, CHAIRMAN
State Supervisor of Science
Maine Department of Education
Augusta, Maine

Mr. Sebastian J. Cultrera
Instructor
Robert W. Traip Academy
Kittery, Maine

Mr. Harold H. Webb
Science Consultant
North Carolina Department of Education
Raleigh, North Carolina

Mr. John P. Neal, RECORDER
Senior Supervisor in
Education (Geography)
Massachusetts Department of Education
Boston, Massachusetts

Mr. George Hupper
Instructor
Southern Maine Vocational
and Technical Institute
South Portland, Maine

Panel 6 addressed itself to the question: "Is there a place for ocean science in today's curriculum?" The panel had some definite ideas as to how and when ocean science topics should be introduced. These points are summarized in the following:

(1) The group was virtually in complete agreement with the idea that ocean science topics should be introduced very early in the school science program. There was some difference of opinion as to the precise level at which the topic should be introduced. Falmouth school representatives, however, indicated that students have an exceptionally high interest in these topics in the very earliest grades.

(2) All members of this group were particularly concerned that teachers should use appropriate instructional techniques or approaches when introducing ocean science topics. They emphasized the fact that students should actively participate in investigational activities, actually working with the raw materials of ocean science in their program. For example, as one participant said, "If children are going to study life of the mudflats, then let's get them out on the mudflats where the life is." Furthermore, the group felt that there was nothing more interest-deadening than a fact-oriented, highly verbalized approach to this subject. They spelled out the fact that teachers must give a great deal of thought to developing for students stimulating and provocative experiences designed to promote the desired interest and enthusiasm. It seemed especially important to this group that the activities planned for ocean science topics should be designed to develop and sharpen observational techniques in order that the child might become more sensitive to the individual stimuli present in his environment.

3. The group recommended that ocean science content be an integral part of the science curriculum with topic sequences planned so that reinforcement by repetition through a spiral approach would be provided in grades K through 6. It was pointed out that any consideration of special courses (i.e. oceanography or expansion of present earth science courses to include these areas of study) should be delayed until the

secondary school level. Many of the panel members felt that it is not necessary to introduce a separate course in oceanography since there are many ways the present curriculum may draw on ocean science topics to enrich existing areas of the curriculum.

(4) The problem of an insufficient number of adequately trained teachers for this particular subject area was recognized by the panel and the following suggestions were presented:

(a) That schools make greater use of local resource personnel to supplement the educational staff. Such personnel should be selected with care to insure that these resource individuals can bridge the gap between the technical sophisticated considerations of the scientist and the embryonic interest stage of the youngster. The language of the scientist must be at a level that the child can comprehend.

(b) That steps be taken to promote in-service training for teachers in the area of ocean science by (a) the introduction of courses at established centers; (b) developing mobile laboratories and museums that bring the ocean to the student and teacher that live inland; (c) obtaining qualified supervisory personnel who would develop teacher interest in acquiring background (this might be stimulated by heightened interest of students); (d) strike at the root of the problem by launching programs at the teacher training institutions to insure that graduates will be qualified in ocean science (the point was raised that the National Science Foundation does provide some summer institute programs at colleges and research facilities to assist in this one area); (e) using educational television networks for teacher training; and (f) using commercial and educational television facilities for informing the lay public of the needs of the schools in relation to marine science topics.

(5) The group raised the problem of the limited availability of resource material for teachers. It was pointed out that current earth science texts provide little in the way of oceanographic content but several sources were identified. It was felt that this information should be available to schools contemplating the introduction of marine science topics.

(6) Although it is probable that some special facilities and equipment may be essential to instruction in marine science topics, the group suggested that much of this equipment could be improvised by local school shop facilities. They did suggest again that mobile facilities would probably be needed to bring the ocean to the inland student and that such mobile facilities might include a simulator so that students might study wave action effects, sorting by streams as they enter the ocean, living animals in salt water aquaria and museum exhibits with accompanying taped stories.

(7) As a final admonition the panel suggested that schools should limit the scope of their marine science program in order that equipment needs and instrumentation costs would not become prohibitive. They specifically advised that schools refrain from moving into a large-boat program since maintenance costs, marine insurance, and stringent maritime

laws create problems that many school systems would find difficult to cope with.

In addition to the discussions leading to the foregoing recommendations, the group received reports on supplementary centers on marine science being planned at Kittery, Maine and at Morehead City, North Carolina, under Title III of the Elementary and Secondary Education Act of 1965. Mr. Sebastian J. Cultrera, the director of the Kittery project which will serve the region embracing Southern Maine and Southeastern New Hampshire, reported that plans were progressing well. He said that they hope to build a marine science facility on Kittery Point at the entrance of Piscataqua River. This site was used during World War II for gun emplacements to protect the Portsmouth Naval Shipyard and, unused since that time, has been acquired by the Town of Kittery after being declared surplus property by the Federal Government. The proposed facility will include an aquarium, an auditorium, classrooms, and laboratories. Mr. Cultrera also described the summer session program on marine biology he was to conduct during the summer of 1966 for twelve outstanding high school students. In addition to a regular schedule of classes, the group was to take a number of field trips, including the State Sea and Shore Fisheries Laboratory at Boothbay Harbor, Maine, and the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Mr. Harold H. Webb described the planning by the Cartaret County Public Schools, located at Morehead City and Beaufort, North Carolina, for an educational and cultural marine science center to be located at Morehead City. The County has received so far from the U.S. Office of Education approximately $15,000 for salaries, office expenses, and travel in connection with the planning of the project. There is considerable interest in ocean science in North Carolina, especially in the 11 counties of the State's 100 counties which border on the Atlantic Ocean or one of its sounds. It is planned that the projected center will serve the following functions:

1. Enrichment of the formal science curriculum of elementary and secondary schools of Carteret County by including fuller exposure to vocational and cultural aspects of marine science.
   a. Revision of the school curriculum to include exposure to ocean science in existing science courses at grades 4-12.
   b. Special marine science courses during school year and summer months for exemplary students.
   c. Lectures and demonstrations in the public schools by locally available, professional personnel, e.g. staffs of University of North Carolina Institute of Fisheries Research, Duke University Marine Laboratory, and U.S. Fish and Wildlife Service Laboratories.

2. General Statewide exposure of school children to marine environments.
   a. Fuller exposure of high school teachers enrolled in summer science institutes.
   b. Use of University of North Carolina educational TV facilities for scheduled presentation of marine-oriented programs.
   c. Use of mobile demonstration facilities with which to bring ocean science to other parts of the State.
   d. Field trips to coastal facilities by classes visiting from inland areas.

3. Enlightenment of general public by expansion of existing museum facilities to include:
   a. Development of public aquarium and demonstration exhibits utilizing proven audiovisual media, including exhibits displayed with sound recordings.
   b. Sponsoring of public lectures and seminars concerning the historical, economic, scientific, and recreational aspects of the marine environment.
   c. Operation of the museum, open to the public and school groups twelve months each year.

SUMMARY AND CONCLUSIONS

Dr. Everett G. Thistle

In summarizing this conference, let me bring you back to the purpose of the conference as stated in the opening. The purpose is to bring together educators and oceanographers and related scientists to explore the means of using our new knowledge of ocean science in the schools. To set the stage for our deliberations we heard stimulating presentations on the importance of oceanography to our national welfare and exciting accounts of recent research in both the physical and biological aspects of oceanography. If anyone of us had any doubts or reservations about the growing national significance of oceanography, they were certainly dispelled as a consequence of these fine speeches.

The real focus of this conference is, of course, the answer to this question: "What is the place of ocean science in the school curriculum?" This is not an easy question to answer, and that is why we have been discussing it here. It seems to me that, as a result of the six concurrent panel discussions which have been held, that there is unanimity that there is a place for ocean science in the schools. There have been scattered attempts to introduce a whole course in oceanography, sometimes as an extra-class activity, into the secondary school curriculum. However, I detect that most of the participants here feel that such a course is not feasible in view of the great demands that are already made upon the student's time. We have been cautioned against introducing narrowly specialized courses and urged instead to teach fundamental disciplines and bring in illustrations and applications from ocean science when appropriate. In fact, our speaker on the higher education aspects of oceanography pointed out that most authorities still believe that oceanography as a discrete subject should be reserved for the graduate school.

We have learned at this conference of significant progress already made in producing teaching units and enrichment materials on ocean science suitable for different grade levels. Examples of these are the oceanology units for the elementary grades produced by Professor Moriarty of the University of Rhode Island, the chapters on oceanography in the Earth Sciences Curriculum Project textbooks, and the oceanography kits produced by the U.S. Naval Oceanographic Office and the San Diego Public School System. These are fine contributions, but more needs to be done along these lines if education is to keep up with the rapid strides being made in the field of oceanography. Another important current development in ocean science education is the establishment of regional marine science centers under Title III of the Elementary and Secondary Education Act of 1965. We have had first-hand reports at this conference on the progress being made on the implementation of such centers at Kittery Maine; Falmouth, Massachusetts; Morehead City, North Carolina; and Inverness, Florida.

My conclusion is that this conference has met its stated purpose in helping to orient each of us to the purposes and possibilities of ocean science and in exploring the place of ocean science education in our elementary and secondary schools. We have arrived at no final, definitive conclusions, but we have made a good start. As Commissioner Kiernan said in our meeting last evening, our assignment does not end with adjournment on this Saturday afternoon, but rather each of us carries a responsibility as he goes from here to work in local, regional, and national programs to bring into full flower this burgeoning program in ocean science and its relationship to mankind.