DEPARTMENT OF OCEANOGRAPHY
UNIVERSITY OF WASHINGTON

Technical Report No. 20

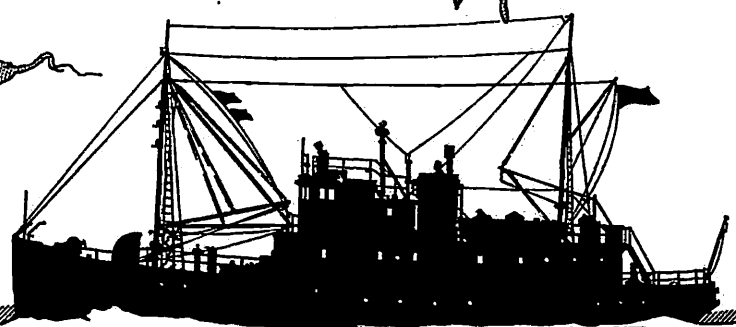
PRESENT STATUS AND FUTURE DEVELOPMENT OF OCEANOGRAPHY

With An Appendix

EDUCATIONAL OPPORTUNITIES FOR OCEANOGRAPHERS IN THE UNITED STATES AND CANADA

University of Washington &
Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 54-4
January 1954



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PRESENT STATUS AND FUTURE DEVELOPMENT OF OCEANOGRAPHY

With An Appendix

Educational Opportunities for Oceanographers
in the United States and Canada

by

Richard H. Fleming

Technical Report No. 20

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Executive Officer

The following paper was presented at the Eighth Pacific Science Congress, Quezon City, Philippine Islands during November 1953. It will be published in the Proceedings of the Congress at a later date.

Due to the number of requests for copies of the paper it was felt that it would be worth while to issue it in mimeograph form to interested individuals and institutions in this country. In order to insure wider distribution it is being released as a joint technical report of the Department of Oceanography and the Office of Naval Research (Contract N8onr-520/III).

Extra copies of this report may be obtained by request to the Department of Oceanography of the University of Washington.

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INTRODUCTION

Among those engaged in the ancient and rewarding profession of teaching, it is often said that "the best way to learn about a subject is to have to teach it." To this I can heartily subscribe, and it is from the vantage point of the professor's podium that I am going to review some of the characteristics of oceanography and to indicate ways in which the scientific study of the seas might be fostered and developed.

Oceanography may be defined as the scientific study of the oceans and of their relation to man. This is intentionally stated in very broad terms. The science of the seas is developing rapidly, its content and concepts are changing, and at this stage of its growth it would be foolhardy to attempt to formulate a precise definition. Because it is a young science and because of the various approaches that have been followed by individual investigators, there is no general agreement as to the content and objectives of oceanography. It is, therefore, essential that I state clearly my own point of view. To repeat the definition: "Oceanography is the scientific study of the oceans and of their relation to man." I am sure that there can be little argument about the first phrase, but it is upon the impact of the seas on man that I wish to place particular emphasis. This brief phrase includes all of the innumerable problems of the applications of oceanography. Some of these are obvious and are well recognized; others are more obscure or have not yet received the attention they merit.

Possibly my position will be more clearly defined if I add the following objectives. I believe that it is the broad purpose of oceanography to understand the present conditions, to interpret past conditions, and to predict future conditions. Many of the most fascinating and important tasks of oceanography are in the borderline fields between the study of the present oceans and the interpretation of the geological and biological history of our earth. It is, therefore, obvious that a proper share of our efforts should be directed towards the development of what may be termed paleo-oceanography in order to properly understand the role that the oceans have played in the development and evolution of life, in the earth-shaping processes of erosion and deposition of sedimentary debris, and in the geochemical partition of the elements.

To turn to the other aspect of oceanography, the ability to predict future conditions, it is in this realm that we find most of the practical or economically-important applications of oceanography. We are dealing with many complex processes that are often beyond the grasp of existing theory. Some predictions, such as those for the tides, have been dealt with in a satisfactory way as far as practical needs are concerned, but it must be recognized that our understanding of the actual physical hydrodynamics of the tidal movements is only fragmentary. The development during the last decade of our knowledge of the growth and decay of wind-generated waves is an inspiring example of the progress that can be achieved when there is an urgent need for a method of forecasting.

I have said that I intended to speak to you as a university professor. This implies that I believe in the importance of teaching

and formal training in oceanography. The topics just mentioned would appear to fall more properly within the spheres of research and engineering applications. Once more to define my position I should say I feel that formal training, research, and practical applications cannot properly be separated. Teaching without research and regard for application is sterile. Applications without training and supporting basic research is self-terminating. Research on the sea without proper knowledge of the subject matter of the science can be wastefully repetitive and neglectful of the important basic problems.

DEVELOPMENT OF OCEANOGRAPHY

I have defined oceanography as the scientific study of the seas. The question may still exist as to whether or not oceanography has yet achieved the status of an independent science. If we briefly review some of the characteristics of a science, I am sure you will agree that, although it is still young, the science of the seas is an individual field of natural science.

To deserve recognition on its own merits, a science must have developed its unique techniques and its own individual body of knowledge. It is obvious that in the early phases of investigation in a new field the techniques employed are initially those of the older sciences. The unique problems involved in the investigation of the biological, geological, chemical, and physical characteristics of the seas can only be attacked by special devices, and the last seventy-five years have been marked by the development and use of techniques that are peculiarly restricted to such investigations. The sonic

depth finder and the GEK (Geomagnetic Electro-Kinetograph) might be cited as examples of what I have in mind.

Just as early techniques are drawn from the established sciences, so the results of early researches published in the existing scientific journals are assimilated into the knowledge of their respective fields. However, with the development of individual techniques and the growth and expansion of oceanographic knowledge, journals and other means of publication have been established and have grown to a point where the subject matter has long since outgrown the parent sciences from which oceanography can be traced. The rapid increase in the number of periodicals devoted to contributions in oceanography, as well as the ever-increasing number of individual volumes concerning the oceans, offers clear proof that there is now a unique body of knowledge that is not assimilated into the older parent sciences.

To achieve status as an individual science it is obvious that the field must be recognized as a profession; that is, experts in the field must be employed under the title of their specialty. This means that the government, industry, and the public in general must recognize that this is a unique profession. Last but not least, universities and scholars in general must accept the field as worthy of admission to the exclusive ranks of academic subjects appropriate for teaching as well as for research.

Oceanography, in the United States at least, has met all of these requirements and must therefore be prepared to accept the responsibilities as well as the privileges that accompany independence and maturity. These responsibilities involve not only the development of the science in all its aspects but also the broadening of the scope

of teaching and research so that students and investigators in other subjects may have the opportunity to glean from the harvest of oceanography those items of particular value to them.

CHARACTERISTICS OF OCEANOGRAPHY

Oceanography always has been and always will be a truly international science. The water masses and the life in the seas recognize no arbitrary man-made boundaries, and the problems that must be dealt with are common to all countries engaged in marine investigations. The oceans are so vast and their problems so complex that satisfactory progress in their study can only be achieved through the combined efforts of all nations.

If the observational data are to be accurate, easily understood, and readily usable, it is obvious that there must be uniform standards of accuracy, uniform methods of analysis, and generally accepted units for reporting of data. The world-wide use of Standard Sea Water (Eau de Mer Normale), prepared in Denmark, as the precise standard for salinity determinations is a classic example of the value of uniform standards. That this service is of importance on an international basis is shown by the fact that it now receives financial support from the United Nations Organization through UNESCO and is sponsored by the International Association of Physical Oceanography. As a step towards the standardization of methods of chemical analysis, treatment and analysis of data, the latter organization also has in preparation a "Technical Handbook on Physical Oceanography."

To further facilitate the exchange of new ideas and techniques and to attain the desirable uniformity in standards and methods, it is

essential that there be frequent or continuous contacts between the workers in different countries. With the development of formal teaching and training in oceanography serious efforts should be made to expand the international exchange of faculty members and students. The Pacific Science Association has sponsored scientific meetings for the exchange of techniques and knowledge, and it would seem entirely appropriate for the Association to consider ways and means to promote the exchange of students for periods of training and research. On the agenda for this Congress is a proposal for the establishment of an International Oceanographic Society of the Pacific. There is definite need for such a permanent organization to assist in the development of oceanography in the Pacific, and I trust that it will receive your vigorous support.

The operation of survey and research vessels is a large financial item that is usually beyond the capacity of individual universities and endowed laboratories. It is a historical fact that vessels engaged in extensive programs have always received national or state support. This type of aid is essential and must be provided on a long-term basis. The money and time involved in outfitting, readying, and training a staff for oceanographic work represent a large investment. It is, therefore, poor economy to embark on short-term programs. Furthermore, the day when single cruises will add materially to our knowledge of the sea will soon be past. Emphasis is shifting more and more to the systematic surveys that will provide information on the seasonal variations and year-to-year differences in conditions, and to intensive studies of some particular characteristic of the sea.

There is another aspect of oceanographic work of this type requiring continued and adequate support; that is the analysis, compilation,

and publication of the results. Because of the mutual interest of all workers in this material it is of international concern, and it is very gratifying to know that the Pacific Science Association is seeking ways in which to promote such a program for the Pacific.

My remarks have stressed some of the major aspects of oceanography, but it would be grossly misleading if I left you with the impression that only those agencies having large resources in vessels and personnel were capable of making significant contributions to our understanding of the seas. Besides the problem of the open ocean there is a vast array of topics that can be attacked by those with only small vessels, modest laboratory facilities, and limited equipment. The shallow coastal waters, including the intertidal zone, are characterized by extreme variability both in space and time. They also represent the region of concentrated human activity. Partly because of the complexity of the inshore waters and partly because of the romantic lure of the open ocean, very little work has yet been done to establish the physical, chemical, biological and geological characteristics of these shallow waters and to understand the processes that influence them. Systematic observations to learn the character of the annual cycles, studies of spawning and life histories of organisms, investigations of fouling, and analysis of the effects of man-made changes such as dredging or harbor construction are but a few examples of the valuable projects that can be effectively handled by those with limited resources.

For those investigators who wish to concentrate on laboratory work there is always the opportunity to obtain material from the larger organizations, most of whom desperately need assistance in the examination or analysis of samples. The use of models to elucidate the

complex phenomena of waves, tides and mixing processes offers innumerable problems for those of an inventive turn of mind. Lastly, there is much that should and must be done to bring together in an integrated form the results of individual cruises or agencies. This geographic approach is one that will bring valuable returns to those with the patience and ingenuity to synthesize the field work of others. Just as all nations with an interest in the seas must participate in oceanographic work, so must all individuals, each contributing to the extent of his opportunities, background, and interests.

Although I do not feel I must justify research and surveys in oceanography, it is desirable to explain why I believe that there should be increased effort devoted to marine investigations. If you accept the premise that oceanographers are concerned not only with the present-day oceans but also with both past and future conditions, then it is possible to see how oceanography has innumerable important applications. In some cases these applications are purely scientific; in other words, the results are either a stimulus to other fields of research or provide information that is essential for the advance of knowledge in such fields. The study of long cores of deep sea sediments is an example; from such cores it is possible to reconstruct certain features of the earth's environment. Because sedimentation in the deep ocean is a continuous but an exceedingly slow process, cores now available represent a condensed history covering at least several million years.

Clues as to the past climates, periods of volcanic activity, and other information that can be gained from such cores are of immediate interest to workers in many fields of science. Such investigations that are of wide interest also tend to attract the attention of other

investigators and hence serve the desirable purpose of bringing new techniques and talents to bear on these problems. The petroleum industry has been particularly generous in its support of oceanographic work because of the needs that exist for better understanding of the conditions under which oil-bearing sediments were deposited. This is an example of how studies in a branch of oceanography, namely submarine geology, are of indirect value in the search for petroleum deposits.

We do not have to seek very far to find instances where oceanography is of direct economic value. The numerous projects falling under the general heading of coastal engineering that include harbor design, construction of offshore drilling platforms, the laying of submarine pipelines, etc., all include the requirement for basic knowledge of the environment as well as for engineering data. It is problems of this kind that have focused attention on serious gaps in our understanding of the oceans.

The examples that I have given to illustrate the importance of oceanography have stressed problems in science, technology, and engineering. Actually the oceans exert tremendous influences on our lives, and these often extend far beyond the earth sciences. The design and operation of vessels depend upon an understanding of the characteristics of the seas, and in the realm of hydrography there are many ways in which oceanography can be applied to improve the efficiency and comfort of vessel operations. The currents and winds and waves that affect the ships of today are undoubtedly similar to those that influenced the craft of those who first ventured to sea. Consequently, there are many aspects of the spread of primitive peoples, the history of exploration, and the development of trade routes that should be examined in

the light of modern oceanographic knowledge. The differing influences of the relatively benign Mediterranean Sea and the stormy, cold North Atlantic upon the cultures of the races in southern and northern Europe involve students in literature, art, and social sciences. The point I wish to emphasize is that there are many facets to the study of the ocean besides those that conventionally constitute the science of oceanography.

THE FUTURE OF OCEANOGRAPHY

The future prospects for oceanography are bright. How rapidly we are able to develop the field depends upon the amount of support provided and upon the number of interested and competent workers in the field. In no other field is there such a deficiency in training as there is in oceanography. Although the opportunities for graduate instruction have been greatly increased since 1940, the demand for personnel has far exceeded the supply. In 1931 I wished to take postgraduate work in oceanography and found that only the Scripps Institution of Oceanography of the University of California provided such opportunities. Today, at least eight universities in the United States offer postgraduate programs leading to degrees in oceanography, and several more provide such training but grant degrees in other departments. Twenty years ago the number of graduate students in training in the United States was less than 10; today the number exceeds 175 (see Appendix).

Although there are eight universities with postgraduate curricula leading to M.S. or Ph.D. degrees in oceanography, there is only one in the United States that provides a major program for undergraduates; that one is the University of Washington. To those concerned with the problems

of training in oceanography, it may be of interest to briefly review why the undergraduate program was undertaken.

In an earlier section of this paper I indicated that oceanography now has its own body of techniques, theories, and knowledge. It is obvious that if training is limited to graduate students, they must either spend an abnormal period of time to complete their work or they must concentrate their efforts on some one phase of oceanography. Because of the lack of textbooks, the difficulties in developing laboratory exercises, and the time required for work at sea and the analysis of data, much of the graduate work has tended to be of a theoretical nature. It is obviously desirable that students receive adequate training in all kinds of work, and this can best be accomplished by starting it early in their career. An added reason for beginning their instruction at the undergraduate level is that only in this way can a continuing supply of competent graduate students be developed.

I do not believe that all students should be trained in the same way--if so, it would obviously be most efficient to concentrate all training in a single institution and to have only a single sequence of courses. For those who wish to enter oceanography at the graduate level, there is the opportunity for choice among a number of universities. For those whose interest has crystallized at an earlier stage, there should be opportunities to start their studies in their chosen field. The general background in basic sciences required for postgraduate work in oceanography by virtually all of the universities is such that a graduate in one of the physical or biological sciences is usually required to take additional courses to make up his deficiencies, as well as to take the necessary courses in oceanography. This is another reason

why it is desirable for students to have the opportunity to acquire this breadth of training as undergraduates, rather than being required to follow the specialized curricula in other fields.

Obviously, an undergraduate program can only be carried on where the oceanographic department is located on the main campus of a university. There are other advantages to such a situation; for example, graduate students with deficiencies are able to obtain instruction in other departments without interrupting studies in their major field. Equally important are the opportunities for both undergraduate and graduate majors in other departments, such as geology, fisheries, and zoology, to take some courses in oceanography to supplement the training in their major field. Furthermore, there is the opportunity to offer general lower division courses, open to students in any department who have to satisfy a science requirement. The University of Washington offers such a course three times a year, and currently there are about 150 students per year who take it as a general orientation and cultural subject. In training, as in research, each institution has certain unique features, and in developing a general program it is obvious that it must be built up to take maximum advantage of its location, facilities, relation to a university campus, and other factors. The Department of Oceanography of the University of Washington has followed this precept.

It would be pointless to propose any ideal plan for individual oceanographic activities, but it is felt that on a national or regional basis there are opportunities to plan for well-rounded programs of education and training in oceanography. The most important factors are to have the universities aware of the needs for training and to have oceanographers reach general agreement as to the character of training

desired and the agencies best situated to give the various programs. This procedure is currently being followed by the Southern Regional Educational Board, an organization that includes representatives of the educational agencies in fourteen states in the southeastern part of the United States.

The undergraduate program at the University of Washington is only in its second year, and several years more must pass before it will be possible to determine its strong and weak points. The program does offer many of the advantages listed above, and it is attracting an increasing number of students. If there is any criticism on the part of the students, it is that the curriculum is too difficult. The number of graduate students is also increasing. To date, most of these have not had any previous training in oceanography, and for such students it has been (and will continue to be) necessary to work out individual programs of study so as to provide the breadth of training that is considered to be essential. For those working towards M.S. degrees, emphasis is placed on formal course work with essentially similar programs for candidates for Ph.D. degrees. A thesis is required for the M.S. degree but this is of much smaller scope than the research that will be expected of doctoral candidates.

Our experience to date has already revealed many difficulties in teaching oceanography that are, I am sure, common to all who undertake formal instruction. Among these difficulties are: how to subdivide the subject matter; the proper sequence of subject matter; the coordination of material presented in different courses; the lack of problems and questions for student work; and the lack of laboratory exercises and experiments. Many of these hindrances can be traced to the fact

that there are no textbooks on the subject. Although there have been a number of books on oceanography published during the last decade, not one of them is appropriate for undergraduate courses, and even more serious, there are gaps in subject matter that are not covered at all. From our experience so far, I would hesitate to say that the time is yet ripe to publish formal textbooks, but they must be considered as one of the major problems confronting oceanographers concerned with education.

Equally important is the development of the laboratory work. There are obviously many aspects of the techniques of oceanography that are suitable for laboratory instruction, and students should also spend time at sea to learn the field aspects of the work.

The deficiencies are, I believe, in ways to help the student visualize the regional characteristics and the nature of the processes at work in the ocean. The most promising approach to these topics seems to be through the development of models. Some of these may be realistic and have a close correspondence to the natural prototype. As an example, I will mention the dynamic model of Puget Sound that reproduces the tides and tidal currents of the area and that has been used to familiarize students with the character of these phenomena. It is felt, however, that there is a real need for ways to demonstrate such features as the heating and cooling, the deep-sea circulation, internal waves, Coriolis force, etc. In such instances it may be impossible to show realistic models, but the conditions may be simulated in some way so that the student can at least "picture" what is involved.

The examples I have given are all in physical oceanography but there is a similar need in the biological, chemical, and geological aspects of oceanography. Teaching aids are also needed for classroom

use. There are no satisfactory large wall charts showing the regional characteristics of the oceans. There is a similar lack in practically all subject matter. In such matters as these, the onus for development must rest on those directly concerned with teaching problems. It is obvious, however, that cooperation, discussion of problems, and exchange of materials on an international as well as on a national scale would be most helpful.

In the earlier sections I mentioned that oceanography must now be treated as a profession. At the present time there is no professional society including all aspects of the science of the seas; furthermore, there are no accepted professional standards. It may be premature to consider what oceanographers with various levels of training should know; however, these are, in large part, the standards that the educator must have in front of him in planning curricula and training programs. It is sincerely hoped that such questions can be discussed at a future meeting of this Congress.

In this paper I have attempted to set before you some concepts as to the nature and present status of oceanography. I have tried to indicate some of the intriguing and perplexing problems that confront us, and the imminent need for the wider recognition of oceanography as a scholarly field for both undergraduate and graduate training. The problems that are involved are of concern to all countries, and I sincerely hope that international agencies such as the Pacific Science Association will continue their interest in such matters.

Attached to this paper is an appendix listing the opportunities for education and training of oceanographers that exist in the United States and Canada. Also included are figures on the number of students in training and those granted degrees during recent years.

10 November 1953
Revised 29 December 1953

APPENDIX

EDUCATIONAL OPPORTUNITIES FOR OCEANOGRAPHERS IN THE UNITED STATES AND CANADA

Oceanography is the science of the seas and it deals with the oceans in all their aspects. Although individual investigators may concentrate their efforts upon physical, chemical, biological, or geological features of the oceans, the science of oceanography is concerned with the development of a comprehensive point of view. The oceans exert a tremendous influence upon man, and the understanding of their characteristics and processes is essential in order to solve many practical problems. The oceans have played a key role in the geological and biological history of the earth, and it is from a study of the ocean waters, marine life, and the sediments deposited beneath the sea that we must learn how to interpret the story of our planet. Oceanography is a pioneer field, it is young, and the number of investigators is small. Advances in recent years have revealed the value of marine research, and the demand for trained oceanographers has prompted a rapid increase in the number of universities offering formal training in this science. Because the requirements and the nature of the training differ in certain ways from those of the older fields of science and because of the interest of prospective students in the field, this brief review of the educational opportunities has been prepared.

The rapid growth in educational opportunities can be traced to the military demands for oceanographic knowledge that developed during

World War II and the shortage of trained oceanographers. Since the termination of the war, government and state agencies have continued to support oceanographic surveys and research and there has been an increasing amount of effort devoted to the oceanographic problems relating to fisheries, coastal engineering, waste disposal, etc. In these problems, industry is providing an increasing amount of financial aid.

It was recognized that full benefit could not be derived from the available funds and facilities unless a proper proportion of effort was devoted to the training of additional personnel. The situation and outlook were clearly stated by Knudsen et al (1950). These authors, after consulting with all interested agencies, outlined a desirable program for the education of oceanographers. Realizing that the individual institutions would meet the situation in different ways, the program was stated in general terms indicating the need for broad training in the basic sciences as well as the nature and amount of course work that should be available in oceanography. Knudsen et al pointed out that it would probably require a minimum of five years' academic work to achieve professional competence in the field. Although no university has adopted the plan in its entirety, it has served as a general objective, each university developing those phases best suited to its individual situation. Additional impetus to the educational program resulted from a survey conducted by the National Academy of Sciences (1952) which was concerned with the need for sustained research productivity.

With the rapid increase in the number of universities involved and the growing number of students who are interested in the science of oceanography, it is of interest to see what the results of the

expanded program have been. In the autumn of 1953, inquiries were sent to all universities and research institutions in the United States and Canada that were believed to be offering one or more courses in oceanography. They were asked to provide information about the courses, whether or not degrees were granted in oceanography, the number of students in training, etc. The data received in response to these requests have been summarized in the following tables.

Table 1 lists the universities and other agencies in the United States and Canada that offer one or more courses in oceanography.* Also shown are the number of undergraduate and graduate courses available and whether or not degrees are offered in oceanography or in some basic field of science. Of the twenty-six activities listed:

(a) Eight offer one or more degrees in oceanography.

(b) Six offer degrees in basic science departments with opportunities to take considerable course work in oceanography.

(c) Nine offer one, two or three courses in oceanography for those majoring in the biological or geological sciences.

(d) Three offer opportunities for marine research without any formal courses in oceanography.

It will be seen that, with the exception of the University of Washington and Texas A & M College, all the programs leading to degrees in oceanography are restricted to graduate students. Although many of the universities offer undergraduate courses, these are in most cases limited to "graduate and selected undergraduates" and are intended

* This listing omits the excellent M.S. program in oceanography provided for Navy aerologists at the U. S. Naval Postgraduate School, Monterey, California.

primarily for graduate students. Several universities offer one general introductory course for undergraduates, but it is only at the University of Washington that a student can take a program satisfying the requirements for an undergraduate major in oceanography. The undergraduate program at Texas A & M College is at present limited to those following a program in meteorology.

The tabulation is as complete as available information warranted; however, the author had to make many arbitrary decisions when compiling the material in Table 1. Differences in academic procedures made it difficult to decide where to draw the line between courses in oceanography (that would be included) and those in related fields or basic sciences (that would be omitted). Those universities that have regularly established departments of oceanography were easily dealt with, and only those courses listed by the department were counted. On the other hand, it was difficult to determine the number of courses that should be counted in those universities where some type of "institute" has been established that sponsors programs based on the offerings of other departments. In general, the courses as tabulated exclude seminars, special topic courses, and those designated for student research. In most cases, each course listed is for one semester or for one quarter. The activities have been arranged in the table in a rough geographic sequence for the Atlantic and Pacific areas, reading from north to south.

Table 2 lists those universities that offer postgraduate training in oceanography and in closely related fields with emphasis on marine sciences. The tabulation shows the size of the teaching staffs and the numbers of graduate students pursuing programs leading to M.S. and Ph.D. degrees in the several subdivisions of oceanography. The final columns show the total numbers of candidates registered in the autumn of 1953.

Table 3 contains the same universities as in Table 2, and the tabulation shows the numbers of M.S. and Ph.D. degrees granted during the past five years. Prior to 1949 the University of California (through the Scripps Institution of Oceanography) was the only university that granted postgraduate degrees in oceanography. Among the remaining ten listed in Table 3, it will be noted that the programs are only from one to four years old and that several have not yet granted a single degree. The University of California has so far borne the major burden of training, but a glance at Table 2 will show that the load is now widely distributed.

The opportunities for training in oceanography can be expected to increase and the number of students to continue to grow. Thus far, the demand for trained personnel has far exceeded the supply, and job opportunities in this field of science are excellent. The work itself is varied and stimulating and provides a productive career for students with an interest and talent for the natural sciences.

Many federal agencies, particularly the U. S. Navy, employ large numbers of oceanographers for both field and office programs. Numerous graduates have been engaged by federal and state agencies to participate in marine fisheries investigations. There are similar opportunities with national, state and local agencies concerned with waste disposal, design of breakwaters and docks, and coastal engineering in general. In recent years there has been an increasing number of opportunities in industry. Petroleum companies have hired many graduates who have specialized in submarine geology, and the industry has called on those with other specialties to assist in designing underwater pipelines and offshore drilling structures such as those built in the Gulf of Mexico.

Because of the expansion of survey and research work, many of those granted degrees in recent years have remained with their university or institution to continue working or have joined another activity engaged in similar work or in teaching.

It would be wrong to assume that the science of oceanography has stabilized. The requirements for personnel are still great and the future demand will depend to a large degree upon the capabilities of the individual students and upon the quality of their training. The place and future of oceanography among the other earth sciences have been examined by the Bureau of Labor Statistics (1952). The nature of the duties involved and the opportunities in the federal service are described in the Examination Announcement for Oceanographer (1953).

Programs in oceanography offered by nearly all of the participating universities are restricted to graduate students who are recruited from those whose undergraduate majors have been in such fields as mathematics, physics, chemistry, biology, geology or meteorology. These students have usually followed the curricula stipulated by their major departments, and rarely, if ever, do they have the breadth of training in the basic sciences required for postgraduate work in oceanography. No general pre-oceanography program, designed to provide the desired preparatory training, has been devised. Each university has its own set of prerequisites which differ considerably depending upon the type and variety of courses offered. At a minimum, most students are expected to have had at least a single one-year course in the basic sciences listed above. Very few enter graduate work with such a broad experience and consequently are required to remove deficiencies in these fields as well as carry a heavy program of courses in oceanography.

This means that unless they have planned in advance to enter oceanographic work and have acquired a broad background, their graduate program will be extremely heavy. It is therefore obvious that all students contemplating graduate work in oceanography should communicate with the universities of their choice at as early a date as possible in order to determine the best type of preparatory program for them to pursue.

A number of universities offer one or a few courses in oceanography that are open to undergraduates, but only the University of Washington provides a full program leading to the Bachelor of Science degree in oceanography. The objectives of this program are to provide adequate courses in the basic sciences and broad training in the subject matter of oceanography. To achieve professional competence, students will be encouraged to continue beyond the four-year program and will be advised to take additional work in the basic sciences. Candidates for M.S. and Ph.D. degrees who enter the graduate school without previous training in oceanography are expected to remove any deficiencies in the basic sciences and, during the early part of their program, to acquire a broad training in oceanography before they specialize in any one field of the science.

For the convenience of those interested in the educational opportunities in oceanography, the addresses of all activities listed in Table 1 are given in Table 4.

The information given above shows that oceanography is a vigorous if relatively young science. It should be attractive to those whose interests are directed towards the natural rather than the laboratory sciences. Because it is young, the pattern of training and the job opportunities are varied. It is, therefore, a challenge to

those with imagination and ingenuity for it offers innumerable major problems that cannot be solved without the development of new techniques and theories. These problems range from topics in pure research to those in applied oceanography and in oceanographic engineering. The lure of the unknown is always a strong one, and in oceanography there is ample opportunity for the student who wishes to extend the frontiers of knowledge in a pioneer science.

The author wishes to acknowledge the able assistance of Miss M. M. Allan. This study was supported in part by the Office of Naval Research under Contract N8onr-520/III, Project NR 083 012.

TABLE 1

COURSES OFFERED IN OCEANOGRAPHY

PARENT ORGANIZATION	SUBDIVISION RESPONSIBLE	UNDERGRADUATE COURSES							GRADUATE COURSES							DEGREES OFFERED IN OCEANOGRAPHY
		GENERAL	PHYSICAL	CHEMICAL	BIOLOGICAL	GEOLOGICAL	METEOROLOGICAL	PRACTICAL AND FIELD WORK	GENERAL	PHYSICAL	CHEMICAL	BIOLOGICAL	GEOLOGICAL	METEOROLOGICAL	PRACTICAL AND FIELD WORK	
Harvard University	- - - - - -	-	-	-	-	-	-	-	-	1	-	1	1	-	-	None
Mass. Inst. of Technology	Dept. of Meteorology	-	1	-	-	-	-	-	-	-	-	-	-	-	-	None
Woods Hole Oceanographic Inst.	- - - - - -	-	1	-	1	-	-	-	-	-	-	-	-	-	-	None
Brown University	Dept. of Oceanography	-	3	-	-	-	-	-	-	2	-	-	-	-	-	None (1)
University of Rhode Island	Narragansett Marine Lab.	-	-	-	-	-	-	-	1	-	-	5	-	-	1	M.S.(Biol.Oceanog.)
Yale University	Bingham Oceanographic Lab.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	None (1)
New York University	Dept. of Meteor. & Oceanog.	1	-	-	-	-	-	-	-	7	-	-	-	4	3	M.S. & Ph. D.
Columbia University	Lamont Geological Observatory	No formal courses														None
Cornell University	Dept. of Conservation	1	-	-	-	-	-	-	1	-	-	1	-	-	-	None (2)
U. S. Dept. of Agriculture	Graduate School	-	-	-	-	-	-	-	2	-	-	-	-	-	-	None
Johns Hopkins University	Chesapeake Bay Institute	1	-	-	-	-	-	-	-	6	2	1	1	-	1	M.S. & Ph. D.
College of William & Mary	Virginia Fisheries Lab.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	None
Duke University	Marine Laboratory	1	-	-	-	-	-	-	-	-	-	-	-	-	-	None
University of North Carolina	Inst. of Fisheries Research	No formal courses														None
University of Miami	Dept. of Marine Sciences	1	-	-	-	-	-	-	3	2	1	(3)	1	-	-	M.S. (3)
Florida State University	The Oceanographic Institute	-	1	-	4	-	-	-	-	1	-	3	-	-	-	M.S. (4)
Texas A & M College	Dept. of Oceanography	1	-	1	-	1	-	-	3	4	2	2	2	2	1	B.S.,M.S. & Ph. D.(5)
University of Texas	Inst. of Marine Sciences	No formal courses														None
University of British Columbia	Institute of Oceanography	-	-	-	-	-	-	2	3	4	2	4	-	-	1	None (1)
University of Washington	Dept. of Oceanography	5	3	2	3	2	-	-	2	6	1	2	1	1	1	B.S.,M.S. & Ph. D.
College of the Pacific	Pacific Marine Station	-	-	-	1	-	-	-	-	-	-	-	-	-	-	None
Stanford University	Hopkins Marine Station	1	-	-	-	-	-	-	-	-	-	-	-	-	-	None
Univ. of Southern California	- - - - - -	-	-	-	-	-	-	-	1	-	-	1	1	-	-	None (6)
University of California	Scripps Inst. of Oceanog.	1	3	2	4	2	-	-	1	4	-	-	2	-	-	M.S. & Ph. D.
San Diego State College	Division of Life Sciences	1	-	-	-	-	-	-	-	-	-	-	-	-	-	None
University of Hawaii	Hawaii Marine Laboratory	1	-	-	1	-	-	-	-	-	-	-	-	-	-	None (7)

(1) Degrees granted in science departments.
(2) Degrees granted in Dept. of Conservation.
(3) Numerous courses in Marine Biology and Fisheries.
(4) Ph. D. granted in Zoology and Botany.
(5) B.S. in Meteorology only.
(6) Degrees granted in Zoology and Geology.
(7) Degrees granted in Zoology.

TABLE 2

GRADUATE STUDENTS ENROLLED IN OCEANOGRAPHY AND MARINE SCIENCES

AUTUMN 1953

	TEACHING STAFF	DEGREE CANDIDATES						M.S.	Ph.D.	TOTAL
		PHYSICAL	CHEMICAL	BIOLOG-ICAL	GEOLOG-ICAL	METEORO-LOGICAL	OTHER			
Brown University	1	1	-	-	-	-	-	0	1	1
Univ. of Rhode Island	4	-	-	5	-	-	-	5	0	5
New York University	3[a]	4	-	-	-	-	-	0	4	4
Cornell University	1	-	-	2	-	-	-	0	2	2
Johns Hopkins University	4	10	3	-	-	-	-	8	5	13
University of Miami	-	1	-	23	-	-	12[b]	36	0	36
Florida State University	4	2	1	7	-	-	-	6	4	10
Texas A & M College	13	7	3	7	1	7	-	8	17	25
Univ. of British Columbia	4	3	1	4	1	-	-	7	2	9
University of Washington	7	4	4	4	0	2	-	9	5	14
Univ. of Southern Calif.	-	-	-	-	7	-	-	6	1	7[c]
Univ. of California	18	13	4	7	13	-	3[d]	5	35	40
University of Hawaii	-	-	-	12	-	-	-	3	9	12[e]
Totals		45	16	71	22	9	15	93	85	178

[a] Total faculty of eight in Department of Meteorology and Oceanography.
[b] Fisheries.
[c] Geology Department.
[d] Biochemistry.
[e] Zoology Department.

Note: There are fourteen students pursuing undergraduate programs in oceanography at the University of Washington.

TABLE 3

DEGREES GRANTED IN OCEANOGRAPHY AND MARINE SCIENCES
1949-1953

		1949	1950	1951	1952	1953	TOTAL
Univ. of Rhode Island	M.S.	-	-	5	0	2	7
New York University	M.S.	-	-	-	-	0	0
	Ph.D.	-	-	-	-	0	0
Cornell University	Ph.D.	-	0	0	0	0	0
Johns Hopkins University	M.S.	-	-	1	3	3	7
	Ph.D.	-	-	0	0	0	0
University of Miami	M.S.	-	-	3	4	2	9
Florida State University	M.S.	-	-	2	2	3	7
Texas A & M College	M.S.	-	-	-	3	4	7
	Ph.D.	-	-	-	-	2	2
Univ. of British Columbia	M.S.	-	-	2	2	0	4
	Ph.D.	-	-	0	0	0	0
University of Washington	M.S.	-	-	-	0	0	0
	Ph.D.	-	-	-	0	0	0
Univ. of Southern Calif.*	M.S.	-	-	-	-	-	6
	Ph.D.	-	-	-	-	-	4
University of California	M.S.	8	14	7	12	8	49
	Ph.D.	3	5	6	5	4	23
Total	M.S.	8	14	20	26	22	96
	Ph.D.	3	5	6	5	6	29

* Only cumulative totals available.

Note: First notation in the columns indicates the year in which the authority was given to grant degrees.

TABLE 4

ADDRESSES OF ACTIVITIES OFFERING OPPORTUNITIES FOR EDUCATION AND TRAINING IN OCEANOGRAPHY

Atlantic Coast:

Harvard University, Cambridge 8, Massachusetts
(Biological Laboratory)

Massachusetts Institute of Technology, Cambridge 39, Massachusetts
(Department of Meteorology)

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Brown University, Providence 12, Rhode Island
(Department of Oceanography)

University of Rhode Island, Kingston, Rhode Island
(Narragansett Marine Laboratory)

Yale University, New Haven 11, Connecticut
(Bingham Oceanographic Laboratory)

New York University, New York 53, New York
(Department of Meteorology and Oceanography)

Columbia University, New York 27, New York
(Lamont Geological Observatory, Palisades, New York)

Cornell University, Ithaca, New York
(Department of Conservation)

U. S. Department of Agriculture, Washington 25, D. C.
(Graduate School)

Johns Hopkins University, Baltimore 2, Maryland
(Chesapeake Bay Institute, Annapolis, Maryland)

College of William and Mary, Williamsburg, Virginia
(Virginia Fisheries Laboratory, Gloucester Point, Virginia)

Duke University, Durham, North Carolina
(Duke Marine Laboratory, Beaufort, North Carolina)

University of North Carolina, Chapel Hill, North Carolina
(Institute of Fisheries Research, Morehead City, North Carolina)

University of Miami, Miami, Florida
(Marine Laboratory, Coral Gables 34, Florida)

TABLE 4--Continued

Gulf Coast:

Florida State University, Tallahassee, Florida
(Oceanographic Institute, Alligator Harbor, Florida)

Texas Agricultural and Mechanical College, College Station, Texas
(Department of Oceanography)

University of Texas, Austin 12, Texas
(Institute of Marine Science, Port Aransas, Texas)

Pacific Coast:

University of British Columbia, Vancouver, B. C.
(Institute of Oceanography)

University of Washington, Seattle 5, Washington
(Department of Oceanography)

College of the Pacific, Stockton, California
(Pacific Marine Station, Dillon Beach, California)

Stanford University, Palo Alto, California
(Hopkins Marine Station, Pacific Grove, California)

University of Southern California, Los Angeles 7, California
(Allan Hancock Foundation)

University of California, Berkeley and Los Angeles, California
(Scripps Institution of Oceanography, La Jolla, California)

San Diego State College, San Diego, California
(Division of Life Sciences)

University of Hawaii, Honolulu 14, T. H.
(Hawaii Marine Laboratory, Waikiki Beach and Coconut Island, Oahu)

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Bureau of Labor Statistics

1952. Employment Outlook for Earth Scientists. Occupational Outlook Series. Bulletin No. 1050, 38 pp. Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Examination Announcement for Oceanographer

1953. Announcement No. 4-34-2 (1953). Available from Regional Offices of the U. S. Civil Service Commission and from most first and second class post offices.

Knudsen, Vern O., Alfred C. Redfield, Roger Revelle, and Robert R. Schrock

1950. Education and Training for Oceanographers. Science. Vol. 111, p. 700-703. 1950.

National Academy of Sciences (Committee on Oceanography)

1952. Oceanography--1951, a Report on the Present Status of the Science of the Sea. Publication 208. 36 pp. Available from the National Academy of Sciences.

Department of Oceanography
University of Washington
Technical Report Distribution List

2 Geophysics Branch, (Code 416)
Office of Naval Research
Washington 25, D.C.

6 Director, Naval Research Laboratory
Attention: Technical Information Officer
Washington 25, D.C.

2 Officer-in-Charge
Office of Naval Research
London Branch Office
Navy #100, Fleet Post Office
New York, New York

1 Office of Naval Research Branch Office
346 Broadway
New York 13, New York

1 Office of Naval Research Branch Office
Tenth Floor, The John Crerar Library Building
86 East Randolph Street
Chicago, Illinois

1 Office of Naval Research Branch Office
1030 East Green Street
Pasadena 1, California

1 Office of Naval Research Branch Office
1000 Geary Street
San Francisco, California

1 Office of Technical Services
Department of Commerce
Washington 25, D.C.

5 Armed Services Technical Information Center
Documents Service Center
Knott Building
Dayton 2, Ohio

1 Assistant Secretary of Defense for Research & Development
Attention: Committee on Geophysics and Geography
Pentagon Building
Washington 25, D.C.

1 Office of Naval Research Resident Representative
University of Washington
Seattle 5, Washington

2 Assistant Naval Attache for Research
American Embassy
Navy #100, Fleet Post Office
New York, New York

2 Chief, Bureau of Ships
Navy Department
Washington 25, D.C.
Attention: (Code 847)

1 Commander, Naval Ordnance Laboratory
White Oak
Silver Spring 19, Maryland

1 Commanding General, Research and Development Division
Department of the Air Force
Washington 25, D.C.

1 Chief of Naval Research
Navy Department
Washington 25, D.C.
Attention: (Code 466)

8 U.S. Navy Hydrographic Office
Washington 25, D.C.
Attention: Division of Oceanography

2 Director, U.S. Navy Electronics Laboratory
San Diego 52, California
Attention: (Codes 550, 552)

1 Chief, Bureau of Yards and Docks
Navy Department
Washington 25, D.C.

1 Commanding General, Research and Development Division
Department of the Army
Washington 25, D.C.

1 Commanding Officer, Cambridge Field Station
230 Albany Street
Cambridge 39, Massachusetts
Attention: CRHSL

1 National Research Council
2101 Constitution Avenue
Washington 25, D.C.
Attention: Committee on Undersea Warfare

1 Project Arowa
U.S. Naval Air Station
Building R-48
Norfolk, Virginia

1 Department of Aerology
U.S. Naval Post Graduate School
Monterey, California

1 Chief of Naval Operations
Navy Department
Washington 25, D.C.
Attention: Op-533D

1 Commandant (OAO), U.S. Coast Guard
Washington 25, D.C.

1 Director, U.S. Coast & Geodetic Survey
Department of Commerce
Washington 25, D.C.

1 Department of Engineering
University of California
Berkeley, California

1 The Oceanographic Institute
Florida State University
Tallahassee, Florida

1 U.S. Fish & Wildlife Service
P.O. Box 3830
Honolulu, T. H.

1 U.S. Fish & Wildlife Service
Woods Hole, Massachusetts

2 Director, Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

1 Director, Chesapeake Bay Institute
Box 4264, RFD #2
Annapolis, Maryland

1 Director, Narragansett Marine Laboratory
Kingston, R. I.

1 Head, Department of Oceanography
University of Washington
Seattle, Washington

1 Bingham Oceanographic Foundation
Yale University
New Haven, Connecticut

1 Department of Conservation
Cornell University
Ithaca, New York
Attention: Dr. J. Ayers

1 Director, Lamont Geological Observatory
Torrey Cliff
Palisades, New York

2 Director, U.S. Fish & Wildlife Service
Department of the Interior
Washington 25, D.C.
Attention: Dr. L. A. Walford

1 U.S. Army Beach Erosion Board
5201 Little Falls Road N. W.
Washington 16, D.C.

1 Allen Hancock Foundation
University of Southern California
Los Angeles 7, California

1 U.S. Fish & Wildlife Service
Fort Crockett
Galveston, Texas

1 U.S. Fish & Wildlife Service
450 B Jordan Hall
Stanford University
Stanford, California

2 Director, Scripps Institution of Oceanography
La Jolla, California

1 Director, Hawaii Marine Laboratory
University of Hawaii
Honolulu, T. H.

1 Director, Marine Laboratory
University of Miami
Coral Gables, Florida

1 Head, Department of Oceanography
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College Station, Texas

1 Head, Department of Oceanography
Brown University
Providence, Rhode Island

1 Department of Zoology
Rutgers University
New Brunswick, New Jersey
Attention: Dr. H. K. Haskins

1 Dr. Willard J. Pierson
New York University
New York, New York