Man and the Sea

by

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I Marine Biology and Biological Stations

On the Pacific coast of North America, from Juneau to Ensenada, there are some fifteen establishments which in one way or another are known as marine biological stations. Some of these operate all year, others open their doors only in the summer time. In the North America alone there are at least 34 marine laboratories associated with Universities. What goes on at these stations? Why are they where they are--or, why do we have these institutions? These are among the many questions asked by interested visitors to marine laboratories, and the announcements that there is to be a new marine laboratory at Bodega Head and that there are plans for a biggest and best one on Catalina Island have stirred up more public interest. Sometimes there are strange notions about the work done at marine laboratories--something mysterious is being done with starfish or crabs or something like that--or the comically serious notion that rats were being raised for scientific torture in the basement at Stanfords Hopkins Marine Station at Pacific Grove. We say this rumor was comically serious because while it did suggest some misunderstanding of the activities at Pacific Grove, the most casual inquiry would have revealed that there is no basement at Hopkins anyhow.

To answer such questions as what marine biology is all about and why people work at marine stations, it seems best to go back to the beginnings with a little history of marine biology and marine stations.

Marine stations, as places--usually some building or another, of course at some seaside location, are not very old. The first one was started about 1859 at Concarneau in France, and is still going. We always say that Aristotle was the first marine biologist, and of course he was, and Charles Singer, the great historian of science, wrote an imaginative description of Aristotle at work:

> "---we see Aristotle, the first and in many ways the greatest of all naturalists, actually watching the creatures he loves. He is leaning out of a boat in the great gulf that indents the Island of Lesbos, intent on what is going on at the bottom of the shallow water. In the bright sun, and in the still, clear water of the Mediterranean every detail, every movement, can be discerned. Hour after hour he lies there, motionless, watching, absorbed, and he has left for us his imperishable account of the things that he has seen with his own eyes."

It is to be noted that Aristotle did not use a microscope; another part of the description should also be noted--undoubtedly Aristotle spent a lot of time observing -- just looking. Too often our modern biologists don't spend enough time in just looking.

Marine biology -- and many other branches of biology, did not really become a serious field of inquiry until the invention of the microscope -- the first good lens systems for microscopes were invented around 1827 and it was not until a few years after that that microscopes became generally available.

One of the first people to make use of such an instrument was evidently a medical inspector at Cork, Ireland, J. Vaughan Thompson. We actually do not know much about this man, other than that he was an army surgeon for many years, who was obviously at heart a naturalist. Between 1823 and 1830 Vaughan Thompson published four papers at his own expense. He worked out the life cycles of barnacles, crabs and hydroids -- these latter are related to sea anemones. To do this he not only used a microscope, he also used a net of fine silk towed through the water to capture the minute immature or larval forms of these organisms. Thus was born the plankton net, still the indispensable apparatus for capturing the minute life of the sea. Some professional scientists did not think too highly of this work -- he was not, as the saying goes, "a man of authority".

The man of authority, who got credit for devising the plankton net, was Johannes Müller, the Professor at Berlin. It was Johannes Müller who set the pattern for trips to the seashore for the study of material, and who advocated the establishment of marine stations. It is often said that Johannes Müller was one of the last great universal naturalists, who tried to keep up with everything and it is suspected that he died in 1858 from what we would call an overdose of sleeping pills. Be that as it may, Müller should be remembered for one endearing gesture -- in his later years, distressed by his doctoral dissertation, he would steal copies back from library shelves and destroy them.

Vaughan Thompson was a highly competent amateur, and Müller was a marine biologist because he was a universal naturalist. The first professional marine biologist, who worked with the creatures of the sea exclusively, was Edward Forbes, the Manx naturalist who lived from 1815 to 1854. His posthumously published Natural History of the European Seas was the first book on marine biology as such.

At the same time a contemporary of Forbes, Philip Henry Gosse (1801-1888) published some of the first popular books on seashore life -- thus starting that type of book that has done so much to attract people of all ages and interests to the sea shore. His books set a fashion in England (and there were similar books by Frenchman and Germans) that stimulated an amateur enthusiasm that has never waned. One must remember another economic factor -- just as the microscope made many studies of seashore life possible, so the building of railroads made it possible for people to reach the shore easily -- and what may be more significant, return in good time to their homes with their specimens. For a while it seemed that no well ordered Victorian parlour was complete without a marine aquarium, and young gentlemen accompanied their ladies to the seashore armed with a handbook to seaweeds or zoophytes and spent the outing learning the names for their mutual edification. There wasn't much else that could be done in those innocent days, evidently.

Some idea of the lengths to which this passion for seashore studies could go can be had from on George Henry Lewes, best remembered by posterity as the principal man in George Eliot's life. In a book titled "Seaside studies at Ilfracombe, Tenby and the Scilly Isles and Jersey", published in 1858, we find this passage:

> "The fact is, the sea is a passion. Its fascination, like all true fascination, makes us reckless of consequences. The sea is like a woman; she lures us and we run madly after her; she ill uses us, and we adore her; beautiful, capricious, tender and terrible! There is no satiety in this love; there never is satiety in true affection. The sea is the first thing which meets my eyes in the morning, placidly sunning herself under my window; her many voices beckoning me, her gently heaving breast alluring me, her face beaming with unutterable delight. All through the day I wanton with her; and the last thing at night, I see the long shimmering track of light from the distant beacon

> thrown across her tranquil surface -- dark now, and solemn, made more desolate by the dark and silent hulls of anchored vessels, but beautiful even in her somber and forlorn condition. I hear her mighty sighs answering the wailing night winds. She lures me to her. I cannot go to bed."

One wonders what George Eliot thought of this passage, written a few years after they ran off together. So much for Mr. Lewes, who was actually a rather good physiologist -- he was not alone as a master of the purple passage -- for as recently as a year or so ago an eminent witness before a congressional committee described the ocean as the placental fluid of the globe. Perhaps a better quotation to remember our Victorian forbears by is that of the Reverend Mr. George Tugwell -- one of several reverend gentlemen who became enthusiastic students of seashore life and authors of books about it -- the Rev. Mr. Tugwell remarked in his little book about the English sea anemones: "But I must add as we stroll homeward, that one great benefit to be derived from the pursuit of natural history at the seaside, is the intense relief and the renewed buoyancy which it grants to a mind wearied and overtasked by the realities of daily life."

Who, in this time of overcrowded daily life, has stated the justification better for such an enterprise as the Pt. Reyes National Seashore?

But let us get back to marine stations and their reasons for existance.

The first impetus for the establishment of marine stations was the great interest in learning more about the plants and animals of the sea, many of them too delicate to be transported away from shore. The early studies soon brought forth much evidence, especially through the identification of developing stages, concerning the relationships of the major groups of animals we call phyla. Most of these major groups are best represented in the sea, and some of them like starfishes and their relatives, occur nowhere else. From the beginning marine stations became necessary adjuncts to university training in zoology, and most of them still serve this function. Many inland institutions require the degree candidates in zoology undergo at least one exposure to seashore life, and the summer enrollment of virtually all marine stations in the United States is filled because of the demand for courses by students from all over the country.

In Sweden this requirement is applied to those who wish to become high school biology teachers -- every candidate must take a course at a marine station. Perhaps we will come to this someday.

But also from the beginning there was a practical motivation for marine stations as well -- the need to understand and improve fisheries and the culture of marine organisms for food. The oldest still functioning marine laboratory, that at Concarneau, was established to study oysters.

Probably the classical laboratory in the sense of pure science is that at Naples, established in 1874 by Anton Dohrn, a german professor. Dohrn started his study of marine life at Helgoland, but after being nearly drowned in a storm, sought a more kindly climate. The Naples station established on an international basis, and is still essentially an international station, receiving some of its support from the United States. People go there to study particular animals and plants, or follow specific lines of study such as the function of squid nerves or the learning behavior of the octopus, and the station is still essentially an international service institution. One rents a "table" which may actually be a small room, and makes his needs known. The scientific fishermen associated with the station usually manage to have the needed animals waiting for the investigator the next morning. One of the early fishermen for the station became so interested that he developed into a first rate specialist in his own right - Salvatore lo Bionco. A season at Naples is considered an essential part of the life of marine biologists, and there are few who have not done some research at the famous Stazione Zoologica.

There is only one such station as Naples.

About ten years after the establishment of Naples the English established The Laboratory at Plymouth. As to be expected, this was peculiarly British, and from its inception, was a mingling of pure and applied science, for one of the patrons was the Royal Fishmonger's Company. Until the last few years, there was no large permanent staff at Naples, but Plymouth has always had resident naturalists, who have worked on problems of fisheries, interrelations of plants and animals in the sea and similar problems which are considered by many to be the stuff of marine biology. The Staff at Plymouth numbers 17 or 20 resident scientists at this time, exploring not only the venerable classical lines of zoology at the seashore, but the problems of life in the sea.

In 1886 the principal marine laboratory in North America was established at Woods Hole. This was actually the successor of summer seaside laboratories started by Louis Agassiz -- perhaps at the instigation of a geologist, Nathaniel Southgate Shaler, a decade or so before. Woods Hole again is a different institutition - administered by a private corporation and not directly affiliated with any single university, although students and faculty members from many universities go there during the summer. The summer population consists of hundreds of people. The rest of the year the great buildings are for the most part unoccupied, although this last year a resident staff was added to undertake studies of the abundances and changes of marine life in the area and to continue the still incompleted task of systematics -- identifying and cataloging the kinds of animals and plants.

Woods Hole has become so crowded that serious consideration has been given to the idea of a "Woods Hole of the West". There are many advantages to the Woods Hole idea, especially the opportunity for investigators to meet and exchange ideas -- although some of them do not study marine organisms at all, but there is also some concern about the advisability of another such establishment which would have so much unoccupied space for a large part of the year.

The nearest counterpart to Woods Hole on the Pacific Coast is the Friday Harbor Laboratory of the University of Washington, located on San Juan island in Pugest Sound. This is actually the second marine station to be established on the Pacific coast, founded about nine years later than the Hopkins Marine Station of Stanford University at Pacific Grove. The original idea behind this station was somewhat similar to that of Woods Hole, -- it was to be a joint enterprise of several institutions. However, it is now essentially a part of the zoology department of the University of Washington. Unfortunately its insular location has made it difficult to undertake year round operations, and it remains primarily a summer teaching and research station.

Stanford's marine station, founded in 1892, is a year round station. This laboratory has a permanent staff of half a dozen investigators and has recently gone to sea in a spectacular way with the TeVega, a sort of scientific school ship for marine biologists. Currently in the Indian Ocean, TeVega carries a dozen students who take course work en route and participate in the first hand experience of working at sea.

We could go on with an itemized list of our Pacific coast marine stations, but in so doing it would be easy to lose sight of the essentials. Marine stations are where they are for several reasons -- usually the location is the best available one nearest the main base -- be it university or fisheries board -- that shows most promise of remaining in a reasonably undisturbed condition. Friday Harbor, for example, is a secluded region with many kinds of organisms and several kinds of environments - muddy, sandy and rocky bottoms, and not too remote from Seattle. It has no open, wave swept shores. The laboratories at Charleston Oregon and Dillon Beach were located at those localities because of the accessibility of several basic kinds of sea and shore environments. Some laboratories, located many years ago, now find themselves surrounded by towns -- these are Hoplins, Cal Tech's lab at Corona del Mar and the great Scripps Institution of Oceanography at La Jolla. But one way or another all afford scientific access to the sea, and to as diversified suite of environments and organisms as possible.

Let us return to the subject of marine biology. While each station serves a slightly different purpose, depending on the institution that supports it and the people that staff it, all have one common aim: to gain a better understanding of the organisms and the processes of the sea. It might be remarked that this does not sound very different from oceanography, but there are differences. Marine biologists at marine stations do not necessarily go to sea, and marine biological stations do not depend on large vessels, nor are they involved in major expeditions. The line cannot always be clearly drawn between marine biology and what some people regard as biological oceanography, nor should it be. But for the most part the scientific effort at marine biological stations is related to the shore and shallow sea, and to the phenomena of organisms that happen to live in the sea. They work from the shore whereas oceanographers work from the sea.

There is work enough for everyone - or, we should say, questions for all. One of the principal questions is how --- and how much do the animals of the sea eat? It is not easy to examine this question on ship board, as precise measurements have to be made not only of microscopically small amounts of food material, but of the amount of oxygen consumed, and carbon dioxide give off, and so on. We have a pretty good idea how much grain it takes to produce a hog for market, or how much fertilzer we must use to grow corn in Iowa, but we know virtually nothing about such matters for the fish, crabs and mollusks of the sea which are major contributors to our fisheries, to say nothing of all the diverse inedible or uneaten organisms along the shore. But we must understand these processes if we are to get anywhere with increasing our harvest of the sea. In recent years we have become aware that our capacity to pollute our environment has increased ten or perhaps a hundredfold in the last twenty years, and we have found detergents in fish livers at sea and radioactive isotopes in oysters far from the sources of the pollution. So we must know much more about how organisms feed in the sea and how various kinds of substances are transferred from one organism to another.

Some of this work is carried on by establishments supported by such organizations as the United States Fish and Wildlife service, but the economic - or practical - orientation of such laboratories often allows little time for the study of problems whose immediate application to the economic problem is not apparent. It is often from disinterested or uneconomic - if we may use the word in that sense - questions that unexpectedly useful knowledge may come.

A famous example of this is the study of the poisonous nature of the Portuguese man-of-war. The French researcher Richet, who was a guest of the Prince of Monaco, was curious about the nature of this poison, and made tests on various animals. He found that sometimes there was no effect until the second test, and thereby discovered the phenomenon of allergy -- which he called anaphylaxis. And who isn't allergic to something or another these days? This is also one of the few discoveries in marine biology to be honored on a postage stamp.

The study of sea urchin eggs -- a perennial favorite for the summer habituees of Woods Hole -- and of Bodega to be, no doubt, has yielded much significant information about the fertilization process -- in fact a current school movie on sex for teen agers shows the fertilization of sea uchin eggs in lieu of the human process -- without, it must be said, making it clear that they are not watching the beginning of human babies. Somewhere in the study of sea urchin embryology may lie a Nobel prize, but in the meanwhile we have learned much about the initial stages of development from this line of inquiry.

Other marine biologists study nerves of squid -- which has some of the largest of all known nerves -- giant telegraph systems that enable the animal to react swiftly, as anyone who has observed squid in an aquarium will remember. Such studies give us insight into the mechanism of nerves -- how they work. Still other marine biologists are interested in the ways by which marine and brackish water organisms -- the creatures of bays and river mouths -- can adjust their salt balance to the changing environment.

As for the plants of the sea, they present many fascinating problems. We have all heard of chlorophyll, perhaps as something that is used to make green toothpaste. But there are different kinds of chlorophyll in different kinds of seaweed, which may have something to do with the circumstance that some kinds of seaweed grow best near high tide while others grow only beneath low tide levels. The efficiencies of these substances is a question of particular interest to those concerned with harvesting seaweeds or hoping to understand the efficiency of the plants of the sea as converters of energy.

These are some of the studies that go on at marine stations. Others are concerned with the more general aspects of the plants and animals in the actual environment -- the broad field known as ecology. Surprisingly little has yet been done on the year to year changes in life along the seashore which may in turn help us understand such spectacular changes as the great sardine collapse of two decades ago, but beginnings of this sort of study have been made at Pacific Marine Station in Tomales Bay and have just been started at Bodega. Without such long range studies we cannot really say what the effects of man's tampering with nature may be.

In these days of governmental support of science, many organizations are actively interested in supporting and fostering marine biological studies at marine stations and university laboratories. Although its primary concern is the application of information to naval problems, the Office of Naval Research has supported many projects which might be considered pure science in addition to supporting research on the habits of creatures that destroy pilings and docks and foul ships and buoys. The navy's interest in developing artificial breathing systems for people and submarines has led to the support of studies of respiration in gills in marine organisms and even such matters as how some types of jellyfish maintain gas in floats. The ability of many marine animals - shrimp, fish, and whales to produce sounds, some of which sound like machinery, is interesting in their own right, is somewhat disturbing to the navy. One interesting by-product of the study of sounds is a record of the various squeaks, rattles and whistlings made by the different kinds of whales and porpoises. Yet, in spite of its concern for practical problems, the Office of Naval Research is one of the most enlightened supporters of research in the sea for its own sake. Research for its own sake is often called "basic research" --- perhaps it would be better to characterize it as inquiry into phenomena without a goal of immediate and specific practical application.

In recent years the Atomic Energy Commission has become an active supporter of such research, especially in ecology, since it has become obvious that if we are to increase our use of radioactive materials, we need to know much more about the present environment of coastal waters in particular. One of the greatest gaps in our knowledge is that of the genetics of marine organisms -- what characters may be inherited and the mechanisms involved. A modest beginning has been made in this field by Victor L. Loosanoff with clams, but until we know much more about the genetics of marine organisms, we are not prepared for the atomic age.

Other agencies, such as the National Science Foundation and National Institutes of Health, support many specific projects in marine biology.

Indeed, the present support and future of marine biology seem to be ahead of the recruitment of able workers. In 1961 over 250 students were turned away from marine laboratories because there was not space enough for them, and 88 were unable to find financing to continue their studies. It is also interesting to note that more than 600 were rejected because of lack of qualification for graduate study - inadequate scholarship is probably the greatest single reason for this rejection. The many young people who have been inspired by films, television and popular articles on marine biology should ponder this unfortunate circumstance, and remember that as in all other fields, the competition is getting rougher every day. But for those who survive, there are few more rewarding careers (except perhaps in actual money) than to be the member of a staff at a marine station -- providing of course that you love the sea and the smell of the shore at low tide and the salt water gurgling gently through your laboratory.

Joel W. Hedgpeth

II Oceanography

Oceanography, the scientific study of the seas and of all that is in and beneath them, is comparatively recent as a formal branch of science. Although mankind has been interested in the sea since before the days of Aristotle, and oceanographic ships have been exploring the seas now for ninety odd years, it is only in the last twenty years that the study of the seas has become a daily way of life for so many scientists and that this endeavor has been supported on such a large scale by governments and universities. Whether or not this support is adequate for the problems that confront man in his hopes for understanding and utilizing the seas is a matter to be taken up later in this series. In any event, growth of interest in and activity in oceanography has been exponential in the past two decades. There are many reasons for this -- some of them related to the war, and the need at that time to understand waves and currents along strange tropical shores, some of them related to the increasing concern over the future of major oceanic fisheries and not least to the increasing popular interest inspired by such inventions as the self contained diving apparatus, which some call aqua lung and others know by its unlovely acronym SCUBA --- short for self contained underwater breathing apparatus -- and the atomic submarines that may move about like fish, almost perpetually beneath the surface.

Today, more people than ever seem to be interested in knowing something about the ocean and about the ways that it is being studied by scientists. Now and then we get the impression that some of these people think the oceanographer -- or oceanologist, as some would call him -- is a different and unique kind of scientist following a very special sort of science only slightly less mysterious than atomic physics. No one has ever defined oceanography in a way that satisfies most oceanographers, because oceangraphy is really not a science in its own right, dealing with a limited suite of phenomena, but simply the scientific study of the ocean and its physical and biological contents. Specialists in many different disciplines are oceanographers -- mathematicians who derive equations for wave patterns or analyse tides, biologists who study the abundance and distribution of plankton - the floating life of the sea - geologists who analyse the composition of the mud at the bottom, and the man who tows a sea going tape recorder through a herd of whales to record their conversation. All these and many others are oceanographers, and some of them do not understand what the others are up to. But they all have one thing in common -- they go to sea for their data.

We usually date the formal beginning of oceanography as Dec. 30 1872, when Her Majesty's Ship Challenger made her first station after leaving Portsmouth on a cruise that was to last more than three years and circumnavigate the globe.. A station, incidentally, is simply a spot at which observations are made -- in this case, at Lat 41°57'N, Long 9°42'W. The depth was 1125 fathoms. Nothing very remarkable was discovered as the dredge did not work quite right and came up half empty - but with enough ice cold bottom mud nevertheless to chill a bottle of champagne to drink to the success of the expedition.

What did we know about the oceans in 1872 that prompted such an expedition? It must not be forgotten that this was not an expedition to chart passages and shoals and rocks for commerce, although some of that work was done, nor was it an expedition to find new lands for the Crown, for there were no unknown lands left. Nor did anyone expect to find fold, spices or other such things. This was an expedition -- and the first such -- sent out to satisfy the curiosity of man.

Exploration of the seas of course did not begin abruptly with the cruise of the Challenger -- for almost twenty years before 1872 British and Scandanavian naturalists had been dredging in deeper and deeper water to find strange and unknown animals. One of the greatest marine naturalists was Edward Forbes - or 4 B's, as he pronounced his name. Forbes studied the waters of the Aegean Sea, but was unable to find anything on the bottom below about 300 fathoms -- 1800 feet, and postulated there was no life on the sea at depths. This of course stimulated others to go deeper and deeper. At this time, in the mid 19th century a new piece of apparatus was developed that made study of the deep sea possible -- the steam donkey engine. Fishermen were quick to adapt this engine to the hauling of larger nets. It was a successor of Forbes, C. Wyville Thomson, who became the prime mover for the study of the deepest parts of the ocean. It was his enthusiasm from the British admiralty, which made survey ships available to him -- vessels named H. M. S Lightning and Porcupine, for the study of the waters north of Scotland.

It was soon apparent that some sort of life was to be found at all depths that could be reached by the bulky rope hawsers and donkey engines of the day, and further questions concerning the oceans were aroused by these preliminary studies carried out during the late 1860's. Furthermore, the advent of steam power to the fisheries greatly increased the haul of fish from the sea, and the beginning of telegraphic communication made it necessary to understand more about the nature of the bottom of the sea, across which the cables must be laid.

Thus was born the Challenger expedition. Although the name of the vessel was singularly apt, it does not appear that the ship was selected because of its name, but because it was available and suitable for the purpose. The Challenger was an early version of a surplus naval vessel, so many of which are now in use as oceanographic vessels in this country. She was a steam corvette, displacing 2,300 tons, which is about equal to some of the medium sized oceanographic vessels now in use, such as the Chain at Woods Hole and the Argo of Scripps Institution. Sixteen of the ships 18 68 pound guns were removed and the ship was converted for use of a floating laboratory. While the officers and crew were regular navy, considerable care was taken to select officers with surveying experience and interest in scientific matters. The Scientific staff consisted of six persons, including the director, C. Wyville Thomson, and the staff artist. Only one of this staff, the german biologist Willemoes-Suhm, had the doctor's degree. The man who was selected at the last minute after another candidate could not accept, became one of the great names in Oceanography. This was John Murray, who succeeded Wyville Thomson as director of the collections and studies and saw the publication of results through to a successful conclusion in 1895, twenty years after the completion of the voyage.

When she returned from her long cruise in the cause of science, the Challenger was decommissioned, and ended up ingloriously as a coal barge. However, her name has been revived from time to time for survey ships, although currently no ship by the name of Challenger is in the oceanographic register.

The Challenger spent more than three years at sea, returning to England on May 24 1876. It was a long and fruitful voyage, expecially for the scientific staff -- except for the loss of Willemoes Suhm, who died at sea. Wyville Thomson survived the expedition by several years, and the remaining young men went on to distinguished and fruitful careers -- John Murray as director of the Challenger Office in Edinburgh, J Y Buchanan the chemist as oceanographer to the Prince of Monaco (in those days the prince of Monaco was a great patron of oceanography), and H N Moseley became Professor at Oxford. Moseley, the son of a mathematician, became an eminent zoologist and one of the founders of the Marine Biological Association of the United Kingdom. It was his son, H. G. J. Moseley who was considered one of the most promising young men of his generation -- in his twenties he determined that the properties of the atom were determined by its nuclear charge. The loss of this young man at the age of 27 in the Gallipoli campaign may have delayed the atomic age by a generation -- certainly this loss had much to do with deferment policies for men of science in the second world war.

The Challenger's track included two crossings of the North Atlantic, a meandering line down the south Atlantic and across to the Cape of Good Hope, Thence to Kerguelen Island and to the edge of the Antarctic continent, north to Australia, through the East Indies, north to Japan and across the north Pacific to the Hawaiian Islands and southward to Chile, around the horn and back through the Atlantic to England. In all, the Challenger logged 68,890 nautical miles on her cruise. For some reason the Challenger did not touch any United States port. In this long cruise she made 362 official stations, lost about 28 thermometers and broke her dredging line eleven times. This is a remarkable record, not often equalled by modern research vessels.

What were the questions that the men of the Challenger - and those who stayed at home - hoped to find answers for in their long exploration of the deeps? First, no one knew how deep the ocean was, or what was on its bottom. It was thought that perhaps the great chalk formation of the Cretaceous period was being actively formed nowadays at the bottom by the activity of organisms -- this idea was known as "the continuity of the chalk." Then it was hoped by some that the expedition would find in the great deeps the survivors of the past -- the trilobites and primitive echinoderms of the paleozoic times, and there was Bathybius, the primordial life substance, a sort of giant amoeba like creature that had been found in the sediment samples made by some of early telegraph cable survey ships. Professor Huxley had named this creature Bathybius haeckeli for his eminent German colleague and there was lively anticipation by some naturalists that this organism might be found in abundance at the bottom. Among the other questions was that concerning the nature of sea water itself -- whether it was uniform the world over, or differed from place to place. But most of all the question was --- what was on the bottom of the sea?

To answer these questions the Challenger dredged the bottom by dragging a net modified from commercial fishing gear, dropped long sounding lines to the bottom, captured water from the depths and took its temperature.

The Challenger found that there was life at the bottom almost everywhere, although she did not achieve the greatest depths -- these were not dragged until 1950 or so by the Galathea - that bottom temperatures were uniformly old, and that sea water was pretty much the same everywhere. No living fossils were discovered - no trilobites or other now extinct forms. Bathybius was never found -- the chemist discovered that Bathybius was a colloidal precipitate of impure sulphate of lime in sea water and bottom mud from the interaction of preserving alcohol and sediment. Thus Bathybius turned out to be an error - as Huxley remarked, it had not fulfilled the promise of its youth. Nevertheless, as the chemist Buchanan said in his report on the true nature of this mysterious primordial plasm, it "should not be allowed to pass into oblivion". Like Forbes' notion of the lifeless nature of the deep sea, it was an error that stimulated thought and research. It does not necessarily follow, of course, that bad ideas are better than good ones, but sometimes a bad idea is better than none at all. Unfortunately some people -- especially brash young one trying to get ahead -- get the notion that they should produce ideas and theories without foundation simply to stir things up. The lesson to be learned from the examples of the lifeless deeps and bathybius is that there was some evidence at the time for these ideas, enough evidence in fact to justify more careful investigation.

One of the major contributions of the Challenger expedition was the report on the sediments -- in which the broad outlines of the deep sea deposits were determined -- and the doctrine of the continuity of the chalk also fell by the wayside. The prime result of the Challenger was the fifty large quarto volumes of reports, whose familiar green bound covers are the cornerstone of every oceanographic library. Most of these concern the life of the sea -- the animals found on the bottom -- and at the surface. Not much was collected in between because the gear was not suitable. The other great contributions are on the chemistry of sea water and the bottom sediments. As far as these aspects of oceanography go, we have been filling in the details so broadly outlined by the Challenger reports. Little was contributed to our knowledge of the circulation of the oceans, because of lack of instruments and the necessary hydrodynamic theories on which to infer circulation from the characteristics of the water. Such theories were not developed until early in this century, primarily by Scandanavian and German oceanographers.

We are still seeking more refined answers to many of the questions raised by those who went on the Challenger expedition, but many more have occured to us as our knowledge has improved.

Now we want to know how many fish there are in the sea, not as kinds, but as populations, and how much the sea can produce as compared to the land -- in terms of plant production and rate of overturn in the food cycles. When the Challenger sailed, ecology had barely begun, with the studies of the oyster banks of Helgoland by the german fisheries biologist Karl Moebius. We often hear from our Sunday supplement literature that as our population increases we must turn more and more to the sea for food and raw materials -- but if we are to do this, we must realise how primitive our knowledge is. It is often stated, for example, that there is no plant activity, or no active synthesis of food in the sea below the depths to which light can penetrate. Yet we are becoming aware that this may not be quite true -- some types of plant like organisms may well be actively producing nutrient material in a different manner. We are also beginning to realise that there is a marvelously complex and interrelated group of rather small organisms in the sediments of the deep seas.

The questions we now ask of the chemistry of the sea water, concern elements and substances not dreamed of by the Challenger's chemist, for now we need to know about the distribution of radium, of artificial isotopes, and other substances of man's careless devising in the sea. Much more refined chemistry is needed now.

Our studies of the sediments go deeper than those of the Challenger's geologists, for now we sink long tubes into the mud and study the layers in these cores to gain some idea of what has gone on in the past. By method the layers of ash that fell into the Mediterranean when Pompei was buried have been identified.

We are vitally concerned about ocean currents and circulation, both as an aid to understanding the populations of fishes and other creatures of the sea, and also as a necessary adjunct to controlling our potential pollution of the sea by radioactive materials and other wastes. While the broad outlines of oceanic circulation have been drawn since the Challenger's time, we may still have such startling discoveries before us that that of the Cromwell Current, a broad thin current flowing beneath the surface in the reverse direction across the Pacific toward the Galapagos Islands --- the existance of this current was not demonstrated until 1950, and the mechanism that drive it is still not well understood. Indeed, there was no provision for such a current in oceanographic theory.

In methods and types of gear we have advanced beyond the Challenger era -- at that time wire cable had just been developed by Lord Kelvin, and was not considered reliable enough -- so the Challenger used hemp lines for sounding and enormous ropes for dredging. The steam donkey engine has been replaced by electric motors. But still the operation takes time -- many hours for a dredge haul. Thermometers are better, and all sorts of electronic gadgets to measure the chemicals in sea water have been devised. Most useful of all have been the echo sounders and similar devices that not only measure the depth beneath the ship but in some cases the thickness of the bottom sediments, producing useful geological profiles. Positioning is of course more accurate. But the prime instrument in oceanography is the oceanographer, whether he be basically a physicist, chemist, biologist or geologist, and the people that help him ashore. It has been estimated that for every researcher on ship, there should be ten ashore to work on the data. But most of these shore people are the indians of oceanography - we need them desperately, but of course most young people who want to become oceanographers want to be chiefs.

Lately we have been trying to decide just what -- or who -- an oceanographer is. In these days of IBM cards and record keeping, everything must be classified properly. There is a federal register of scientific talent, and all working scientists are asked to fill out rather complicated forms for this register. Somebody converts these things to little rectangular holes on IBM cards. Recently in an attempt to estimate the total number of oceanographers, these cards were fed through the machine, and about 5,000 cards fell out. There are nothing like 5,000 oceanographers, even if we count all the cooks and bottle washers. There may be 5,000 people who have something to do with things in, about or from the ocean. For example, I do not consider myself an oceanographer, but a marine biologist, who happens to specialize in the study of a group of animals found only in the sea. But I have become recently involved in trying to promulgate a fool proof questionnaire that will produce only the real oceanographers, those who work actively with problems in the sea and who go to sea. So our questionnaire asks how many months have you been to sea this last year, and what research papers have you published about the sea, and so on. I am not qualified to fill out this questionnaire -- or at least I have managed to do so in such a way that I probably will not be numbered among the salt water oceanographers -- this time my IBM card should fall out in the miscellaneous pile at the end.

There ia a serious aspect to this attempt at classification, since the support of oceanography must depend in part on the estimated roster of available people. There are probably not more than 350 or at most 500 people in the US who really ought to be considered oceanographers. Yet we have plans for adding more and more ships to the scientific fleet and some of us are not too sure that we are going to have enough oceanographers to man these ships, especially at the present rate of recruitment from universities.

An oceanographer is not only a scientific sailor, he is something of a jack of at least several trades. A good many of the senior oceanographers have come from other fields of study, carrying their special problems to the sea. Because of its three dimensional nature, the ocean presents many complications even for the simplest problem, such as going back to exactly the same place on the bottom of the sea to take a second sample of mud or worms. As a result, more knowledge of oceanic processes is expected of the next generation by those who have learned some of these things the hard way. It has been facetiously said -- but perhaps not so facetiously after all -- that present degree requirements are such that many of the people who now hold degrees in oceanography would not now be eligible for admission to graduate schools in oceanography. This is perhaps more simply understood as a result of the increasing numbers of people who want to go on to graduate school, and the correspondingly larger number of those who can meet more stringent requirements - in other words, as in many other fields, the competition is getting keener.

We often get requests from students in high school, and sometimes even from grade school children, about a future in oceanography, and how to study for it. Sometimes we get inquiries from their teachers as well, who seem to want to take to sea to get out of the classroom. Often these questions include inquiries about working hours and salaries. At the outset, it should be realized that oceanography -- like any other scientific endeavor, does not observe union hours and that the principal compensation is not the salary but the privilege of doing what you really want to do and incidentally getting paid for it. As the Greek poet Oppian said so long ago of the fisherman, the oceanographer should be daring, dauntless, willing to lose sleep, and must be keen of sight, wakeful and open eyed. "He must bear well the wintry weather and the thirsty season of Sirius -- he must be fond of labor and he must love the sea."

Preparation for career in oceanography is not easy -- love of the sea is not quite enough. Oceanography is such a mingling of different disciplines and specialities that it is necessary for an oceanographer to know a little bit about almost everything in addition to knowing a fair amount about some particular field.

In other words, there is really no "major" in oceanography. A student should be basically a physicist, biologist, geologist or whatever, interested in the processes of the sea as they pertain to his central field of study. As a result virtually all institutions that offer degrees in oceanography require first of all a major in a particular field, and a broad background in related fields. For example, a biology major who desires to become an oceanographer must also have laboratory courses in chemistry and physics, and at least one course in geology. All oceanographers are expected to have mathematics through calculus. Since oceanography is one of the most international of the sciences, foreign languages are essential and are becoming increasingly more so. The two preferred ones for degree candidates are Russian and German.

The beginner in college should not hope -- or expect -- to start right in with the ocean. Few institutions offer undergraduate majors in marine biology, and only one -- the University of Washington -- offers an undergraduate major in oceanography. But the requirements are so many that the course is really a five year one anyhow. An oceanographer should begin his preparation back in high school, learning his own language -- English in our case -- mathematics and the start of his foreign languages. The best college training for oceanography -- as for any other branch of science -- is to get into the toughest undergraduate school possible, and to work hard. Although oceanography does call for a diverse background training, the diversity can be overdone. There is the sad story of the young man who tried to do everything in his undergraduate years that was hoped for by a committee of oceanographers who published a brochure on the ideal education for an oceanographer. Unfortunately this young man overlooked the essential requirement that he have at least one solid field of specialization. As a result, when he presented himself for admission to graduate school, he was unacceptable for admission because no professor would concede that he had the background for any one subject. Perhaps the story is apocryphal -- but it does serve as a warning that diversity of knowledge must not be confused with diffusion of effort. Anything in excess is bad for the system -- including too much salt or water.

While no one wants to discourage young people, it is only fair to remind them that many are called but few are chosen -- but if the call is strong and the response adequate, there is a good chance of being chosen. It is inevitable that our national effort in oceanography will increase, for we have barely begun to study the oceans and our future will depend much more on our understanding of the oceans than it will upon bringing back samples of moon dust.

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III The ways and means of Oceanography

Public understanding of oceanography - what it does and how it operates - is not always in pace with popular interest in the subject. Too often, questions are asked which suggest that the questioner understands no more than that oceanography involves going out on the ocean with a boat, or down to the bottom in a bathyscaphe, or perhaps drilling a hole through the bottom of the sea. The drilling of a hole in the bottom is only incidentally related to oceanography -- if it is to be done at all, it has to be somewhere in the sea where the earth's crust is thinner, and the budget for the Mohole is separate from oceanographic budgets. Oceanography, is more, of course than people who study the ocean, although the people are the most essential part of oceanography. Oceanography is ships, shore bases, instruments and logistics.

According to the 1961 compilation called Oceanographic Vessels of the world, some 161 vessels of all types were in use as oceanographic research vessels all over the world. The list was probably incomplete before it was published, and some vessels are included which can hardly be considered oceanographic in the fullest sense of the word since they are 39-40 feet long and probably seldom get very far from land. Of the 161 research vessels listed, 43 are in the United States, and only 12 are listed for the Soviet Union. According to a more recent listing of new oceanographic vessels, some 31 new vessels are now in service or will be in the next few years in the United States alone. This however includes some rather special objects, like FLIP, which is a long tube with a cabin on one end that is towed to sea and upended to form a sort of floating submerged tower to study the acustic properties of sea water, and a small two man submarine. Another 43 vessels are conversions. While there is some duplication in the lists, and some of the new ships or conversions will replace others now in service, it is nevertheless evident that the United States is doubling its oceanographic fleet in about ten years time or less. A good part of this increase is due to the so-called Navy Tenoc (Ten years oceanography) program. Each year the Navy is supplying two or more vessels, generally termed AGOR, which is short for Auxiliary General Oceanographic Research. These are not all constructed to a uniform plan, although they are usually 200 feet or more in length. Some are conversions -- adaptations of existing vessels, others are new, specially ocnstructed ships. New research vessels cost between 2 and 3 million dollars to construct, and conversion of an existing ship may cost a half million dollars. Among the AGOR ships is the Eltanin, operated in Antarctic waters by the National Science Foundation as part of the Antarctic Research Program. The Davis, used primarily by the Navy, is based in San Francisco. Another is the Conrad, operated by Lamont Geological Observatory. This is not mamed for Joseph Conrad, but for Robert Dexter Conrad, who had much to do with the Office of Naval Research in its early, formative years. Another group of large research vessels is operated by the Bureau of Commercial Fisheries of the Fish and Wildlife Service. It was the predecessor agency, the U. S. Fish Commission, which built and maintained the first vessel specifically built for the oceanographic research, the Albatross. The name is now carried by the Albatross IV at Woods Hole. A few research vessels are maintained by industries for special purposes such as testing instruments or classified research related to military contracts. In all, it is possible that by 1970 the United States alone will have an oceanographic fleet equal to the world fleet of 1960.

As anyone who owns a boat -- even a fibreglass job with a trailer that is towed out to a lake on weekends -- knows, it's not the initial cost, it's the upkeep, that runs into money. The cost of oceanographic ships is high - good sized vessels cost around 1,000 to 2,500 per day at sea, and the annual ship operating budget of Scripps Institution of Oceanography alone is 2.5 million dollars. These costs include maintenance, but cost os operating ships does account for a large part of the national oceanographic budget. Yet the total budget is not very large. Just how it will work out for 1964 is uncertain, but it will probably be around $140,000,000. This is of course the Federal budget, and includes the share of the Navy, the Bureau of Commercial Fisheries and Coast and Geodetic Survey, Atomic Energy Commission and National Science Foundation. It does not include the money from states and private industry, but this is a small fraction of the total anyhow. It is difficult to estimate the total world wide budget for oceanography, but it seems to be in the order of perhaps 250,000,000 per year.

Even without expansion of effort, oceanography is not going to get less expensive. The cost of operating ships increases steadily -- despite the careless statements of one local oceanographic entrepreneur, universities do not use students as crew to operate research vessels, but unionization of crews on research vessels will produce difficult financial problems. Oceanographic instrumentation is becoming more expensive as the instruments become more complicated -- or sophisticated, and we have now reached the stage where no major oceanographic institution feels properly equipped unless it has a computer. Indeed, one of the latest major research vessels has a computer on board to process results under way. All that is now needed is an attachment that will produce the finished progress reports for distribution when the ship docks. Somebody attempted to reduce the costs of oceanography to specific details and came up with the estimate that each figure, such as a temperature measurement, cost about $7 a number, and a sample of sea water captured in a bottle cost $11 a fifth. Loss of gear is inevitable, and instruments must be replaced. When one remembers that oceanographic vessels often must be at sea in rather rough weather (although of course observations are impossible in heavy seas), it is remarkable that no major oceanographic vessel has been lost at sea in the last twenty five years, and only two since 1929. The French exploring vessel Pourquoi Pas?, a veteran of Antarctic exploration, was wrecked on the shore of Iceland in 1936 with the loss of all but one of her crew, including the commander, Captain Charcot, and the non-magnetic research vessel Carnegie was destroyed in 1929 by fire in Apia harbor, Samoa, with the loss of her captain and a cabin boy. In view of the hazards involved, the safety record of oceanography is much better than driving down the highway. The most disastrous loss to oceanography is recent years was the airplane accident in Mexico which took the lives of Townsend Cromwell and Bell Shimada while en route to join an oceanographic cruise in 1958. A few years ago a vessel from the University of Tokyo was destroyed by a volcano, with the loss of all on board, including some well known students of volcanos, but this is not a usual hazard of research vessels.

The estimated world oceanographic budget of approximately 250 million a year may sound like a lot of money to some people, but it is infinitesimal along side the $5 billion approved for space projects by Congress for fiscal 64. The National Academy of Sciences committee on oceanography recommends an annual budget of 600 million for USA by 1970. While a large part of the oceanography money may be spent for engineering and keeping ships going, a still larger percentage of our space budget is not strictly speaking science -- it is hardware. And there is no comparison of the practical benefits to be obtained by a fuller knowledge of the ocean as compared with finding whether or not there is really life on Mars. Let us say we do find that life is constructed of something other than DNA on Mars -- very interesting, but so what? We still have to live on earth, and the ocean is the largest part of our earth.

As a distinguished British gentleman, Sir Frederick Brundett has remarked: "The World must be mad to spend more in a year on space research than has been spent in studying the oceans in the last hundred years".

Ships, of course, are the primary capital investment of oceanography. But there are also buildings. Oceanographers do not spend all their time at sea, but must process data, analyze results and prepare reports. It has been said that for every day at sea there are ten days of work on land. Another way of putting this is that there should be nine or ten researchers and technicians ashore for each man at sea. This requires buildings, and one of the most striking aspects of our oceanographic institutions is their crowded condition. Nobody seems to have enough space to work in and everybody needs more buildings. Sometimes a close mingling of people has an advantage -- more ideas get exchanged. But there is some limit to this, beyond which people simply get in each other's way.

Our oceanographic effort is not however, overstaffed, even if the buildings are crowded. Indeed, we are not sure where all the people are coming from to staff the vessels and the shore facilities for our expanding oceanographic fleet. Recruitment, in spite of all the public interest, is not as fast as we would like it to be. We think there are about 500 - at the most - real oceanographers in the business in the United States and the shortage is already acute in two fields -- straight physical oceanography (which calls for more rigorous mathematical background than other phases of the field), and taxonomy -- the people who must identify all the kinds of plants and animals found in the ocean, or at least those which are most abundant. According to one federal agency, the manpower requirement for taxonomy is much smaller than for physical oceanography. This was evidently written by someone who did not know what he was talking about, for the identification of organisms is not amenable to computer techniques, and it has taken years to get some of the most important animals identified. Our most critical need is biological oceanographers - good ones, who are specialists in various critical groups of organisms.

At any rate, we have ships -- perhaps more than we need - buildings, but not enough for the people we do have in most places, and people - critically short in some fields. What are we doing with what we have?

There are two broad aspects of oceanographic effort. The first is what is known as surveys -- this is essentially similar to the mission of the Weather Bureau-continuous retaking of observations at the sea to gather data for the changing environment, and to find out what is there at present. One of the great international efforts of this character is currently in progress, the International Indian Ocean Expedition. This involves ships of many nations including USA and USSR. Much of the work of the US Navy's Oceanographic Office, the Coast and Geodetic Survey ships and the Bureau of Fisheries is essentially survey in nature. This must be kept up year after year, although some aspects of it maybe processed by computers for more rapid results. Promising steps in this direction have been taken by the Navy. An adjunct to the survey function of oceanography is the National Oceanographic Data Center, where all data that can be reduced to square holes on IBM Cards is being assembled. The Soviet Union operates a similar data center, and the two are exchanging information.

The other aspect of oceanography is that involving research into special phases or problems -- sometimes this involves surveys as well, but often expeditions are undertaken to explore special problems or phases. Some of these have come to attention because the routine data gathering has brought out problems. So it is not always easy to separate these functions. A survey of fishery areas in the mid Pacific revealed the Cronwell Current or equatorial undercurrent running against the grain, so to speak, just under the equator from west to east. An immediate result of this discovery has been not only intensified study of the oceanic region involved, but a lively reappraisal of basic oceanographic theory, since it did not have any explanation for this observed phenomenon. The intensive, repeated surveys off the California coast, set in motion by the decline of the sardine, have brought to light oceanic fluctuations still not adequately explained, and provided data for a new and critical approach to the organization of groups of planktonic or floating organisms. We even have the glimmer of an idea of what may have happened to the sardines, but cannot say confidently that the "average" or "normal" conditions of the waters along the California coast are conditions of sardine abundance or sardine scarcity. It may take twenty five years of surveys and data to get an answer to that question.

What oceanography should do, at least in this country, has been considered by a number of national committees. In fact, from its beginning oceanography has been organized by committees. A committee of the Royal Society determined the course and scope of the Challenger Expedition that explored the oceans from 1872 to 1876. The oldest committee that still functions is known as the Conseil Internationale pour l'exploration de la Mer, a committee of representatives from various countries of northern Europe, including the Soviet Union -- Russian scientists were among the charter members in 1901. It has confined most of its interest to the North Sea and the North Atlantic, with emphasis on fisheries problems. It is now more familiarly known as ICES, from its English title, International Council for the Exploration of the Sea.

In the United States the course of oceanography has been charted -- or should one say plotted -- by two successive committees of the National Academy of Sciences. The first of these committees flourished in the decade 1927-37. As a result of its deliverations and reports, Scripps Institution was started on its way as a major center of oceanographic research and new establishment was recommended for the Atlantic Coast. Accordingly Woods Hole Oceanographic Institution (not to be confused with the much older Marine Biological Laboratory there) was founded in 1931. At the present time there are four research establishments at Woods Hole, employing in all hundreds of people. It is a town whose chief industry is science. And tourists in summer time -- scientific and otherwise.

The present committee on Oceanography of the National Academy, familiarly known as NASCO, was established in 1957, and is responsible for much of the stimulus that has prompted Congress and the various granting and contracting agencies of the Federal Government to support oceanography.

ICES and NASCO are not the only committees. There is a veritable galaxy of committees, both international and in each maritime country. Attempts to coordinate oceanographic effort in the United States, at least in the Federal bureaus, are made through ICO, the Interagency Committee on Oceanography, not to be confused with IOC, the Intergovernmental Oceanographic Commission, and SCOR, the special Committee on Oceanic Research. Both of the latter are part of UNESCO. A recent publication of the United Nations lists some 45 committees involved in one way or another in oceanography. In spite of all the multiplicity, there is a sort of oceanography establishment. The same eminent individuals serve on several committees and shift about in a sort of game of musical chairs from one committee meeting to another. Now and then our committees seem to get a bit weary, and the last joint meeting of NASCO and ICO could only approve what was already decided and further recommend air-sea interface studies as the most important thing yet to do.

From the sense of all these meetings has come statements of the broad aims of oceanography. The ICO has surmarized these in terms of five objectives: One - to describe the distribution of physical and chemical properties of the oceans and to understand the dynamic processes which affect this distribution; two - to increase knowledge of interactions between sea and atmosphere; three - to determine the kinds, distribution, adaptations and productivity of the living populations of the sea and to understand the interactions of the marine organisms to each other and to the physical and chemical properties of the sea. This is to many of us the ultimate and most essential mission of oceanography, and all other objectives relate directly to it. Already the potential backlog of specimens that must be handled from our increasing oceanographic effort has resulted in the establishment of anew division of the Smithsonian Institution to sort the specimens and see that they are placed in the hands of those who will study them. The fourth objective is to describe and understand the geological, geochemical and geophysical nature of the sea floor, including its relation to the adjoining land masses. Insofar as the Mohole can be considered oceanography, it will fulfill a small part of this objective. The fifth and last major objective is to determine the modification of the ocean resulting from man's activities. It is reassuring that at the highest levels of our committee establishment this problem is recognized. Nor too many years ago the possibility that man could alter the ocean was not seriously considered at all.

These objectives are carried out not only by the large government agencies such as branches of the navy, coast and geodetic survey -- and the army, which because of its charge for harbor engineering, studies beaches and harbors, and the Fish and Wildlife Service, but by universities and private research institutions. There are three big oceanographic institutions as such in this country, Scripps Institution (not Institute, please) at La Jolla, the Woods Hole Oceanographic Institution at Woods Hole and the Institute of Marine Science at Miami. There are quite a few other oceanographic institutions and departments of universities, and there is even an oceanography department at Ann Arbor, Michigan.

The work, of course, is actually done by oceanographers and the people at the shore bases. The usual procedure is for those who actually want to do the work to propose their project. Funding is provided in one way or another, through grants or contracts. But the growing problem is that ship time eats up so much of these budgets (since usually ship time is charged against each project) that serious concern is now being expressed. It seems inevitable that ways must be found to operate ships separately from specific missions as well as developing more realistic accounting systems. One oceanographic ship operated, according to the books, 13 months in one year!

In any event, the broad mission has filtered down from the establishment, and a lesser committee somewhere has approved the project and the money. Finally the oceanographer can go to sea.

The life of an oceanographer at sea is not much different from that of the commercial fisherman -- getting good data or observations is often as uncertain as making a good catch of fish. Nor is it always certain that instruments will work properly. Most of them do, but there is always the peril of a parted cable -- and the valuable gadget sinks to the bottom. One of the informal standard rules of oceanography is that you should photograph a new piece of apparatus before you lower it in the ocean, because that is the last you may see of it. Data must be gathered at all hours of the day and night, and sometimes the process takes most of a day. Some samples must be analyzed immediately and others properly stored for later analysis ashore.

But data alone is not science. It is not enough to do something that hasn't been done before -- to sail to an unknown spot on the ocean just because no one else has got there yet. The critical need in oceanography, as in all branches of science, is for keen analytical minds to make useful summaries of data and draw meaningful inferences.

Without people of this sort, our national oceanographic effort can become constipated with data. So far, however, provisions for education of oceanographers are the smallest part of our budgetary thinking. It is to be hoped that this will not continue to be so.

Joel W. Hedgpeth

who said:

> But, since the sea is infinite and of unmeasured depth, many things are hidden, and of these dark things none that is mortal can tell; for small are the understanding and the strength of men. The briny sea feeds not, I think, fewer herds nor lesser tribes than earth, mother of many. But whether the tale of offspring be debatable between them both, or whether one excels the other, the gods know certainly; but we must make our reckoning by our human wits.

Indeed we must, and one of the liveliest arguments among oceanographers and marine biologists is precisely the question put by Oppian around 180 AD: does production in the sea equal or excel that on land? At least we hope that our understanding and our wit have been sharpened since Oppian's day, and we may not be too far from some sort of answer to this basic question of the productivity of the sea. In the meanwhile, popular writers and TV script artists oversimplify the problems and raise hopes whose fulfillment we cannot guarantee.

Consider, for example, the following statement from a recent magazine article:

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IV The Inexhaustible Sea

The title of our discourse is taken from a recent magazine article, but it illustrates an opinion about our future expectations from the ocean that many informed scientists view with some reservation. It is true that the seas of the world cover the greater portion of the globe and that much can be expected from them in the future. But our knowledge of the seas is only slightly less fragmentary than that of the moon, and some of the schemes and imaginative devices proposed for obtaining resources from the ocean are only slightly less fanciful that the devices suggested for bringing a sample of moon dust back to earth, and almost as expensive.

The optimism of those who speak of the inexhaustible sea had best be tempered by a remembrance of how we have regarded our terrestrial resources. It was not much more than 60 years ago that men still spoke of the boundless wealth and inexhaustible resources of the North American continent. Now we seem to have transferred this attitude to the sea, but we have no real justification for doing so. In short, our estimate of the inexhaustible resources of the sea is based on our lack of understanding of the sea. It is also part of man's blithe optimism that the future will always be taken care of, somehow. But the gloomy prophets of the plundered planet school (as some have disdainfully called them) are right in one essential: mankind cannot always hope that the future is assured, unless he limits his numbers so that they do not exceed the carrying capacity of the earth. The solution to Los Angeles is not to commit all the water of the western United States to its unlimited growth, but to stop Los Angeles from growing. One of the plans for moving water to Los Angeles would be so devastating to fish life, especially what is left of the salmon, that the Fish and Game people have categorically recommended against the scheme. Thus what we propose to do on land may affect the life of the sea and our expectation of future harvest.

But there is also the implicit notion that we can do almost anything we wish to our native environment, the land, as long as we have the sea to fall back on. But because we are creatures of the land, the sea will always to our secondary reserve -- and what will it avail us to reduce our land to a vast denaturalized desert of houses, highways, power plants and turn to supporting ourselves on fish meal and plankton soup -- if indeed that is possible? Man will not be able to live on fish meal alone.

The eminent fisheries biologist Sir Alister Hardy has pointed out that apparently several times in the history of life on earth certain animals have been forced back into the sea to make their living. Porpoise and whale like dinosaurs evolved, and in later epochs the mammalian whales, seals and such birds as auks and penguins evolved from terrestrial relatives. Perhaps this was due to competition for food. Sir Alister goes on to remark that man's increasing populations will force him back to the sea as well -- and he proposes a few fanciful devices of his own -- underwater fish herding gadgets and perfected diving apparatus that will enable us to stroll about in far deeper water than we can now reach. At any rate, it is to be noted that this return to the sea will not be the result of competition from another, more successful terrestrial mammal, but from man's own pressure of numbers. Are we justified in the comfortable notion that the sea is our ultimate safety valve?

The problem was concisely put some 1800 years ago by the greek poet Oppian, who said:

> But, since the sea is infinite and of unmeasured depth, many things are hidden, and of these dark things none that is mortal can tell; for small are the understanding and the strength of men. The briny sea feeds not, I think, fewer herds nor lesser tribes than earth, mother of many. But whether the tale of offspring be debatable between them both, or whether one excels the other, the gods know certainly; but we must make our reckoning by our human wits.

Indeed we must, and one of the liveliest arguments among oceanographers and marine biologists is precisely the question put by Oppian around 180 AD: does production in the sea equal or excel that on land? At least we hope that our understanding and our wit have been sharpened since Oppian's day, and we may not be too far from some sort of answer to this basic question of the productivity of the sea. In the meanwhile, popular writers and TV script artists oversimplify the problems and raise hopes whose fulfillment we cannot guarantee.

Consider, for example, the following statement from a recent magazine article:

> "--- the sardine population dwindled, and it never recovered, because by the time the environment improved in 1957, the feeding grounds has been pre-empted by a kind of anchovy that has a limited market as a food fish in the United States. Had the anchovies been fished intensively during the lean year, Cannery Row might still be thriving."

There are so many oversimplifications in this statement that it is hard to know where to begin. However, it should first be pointed out that at the peak of the California sardine fishery - around 1936-39 - the greater part of the catch was not used for human food but for the production of fish meal for livestock food and oil for industrial purposes. The same thing is happening to the herring fisheries of Europe. The peak production of California sardines has now equalled or surpassed by the menhaden fishery of the South Atlantic and Gulf states, which in 1961 accounted for about 45% of the entire fish catch of the United States and Alaska. Menhaden are used exclusively for fish meal and it is obvious that menhaden have replaced sardines in the economy. It is doubtful, should the sardines return this month, that Cannery Row could ever catch up. The State of California controls the percentages of whole fish that may be used for reduction purposes, and at this time virtually the entire sardine -- and anchovy-catch is canned for food. 1961 was the lowest sardine pack in history. Of course, some people might say that Cannery Row is thriving again -- as a tourist trap.

The most serious misstatement is perhaps the idea that had we been as fond of anchovies as of sardines as food, the fish canneries would have been able to continue at something near their peak by simply switching fish and labels on the cans. The idea that anchovies are replacing sardines is at best a hypothesis, and I am not aware that anyone who has studied the situation would be willing to say that this was an instantaneous replacement of fish stocks, like changing the guard at Buckingham Palace. It will be interesting to see what happens if the menhaden population collapses -- what will happen then to the cannery rows of the Atlantic and Gulf coast communities? When the herring disappeared from the baltic in the mid 15th century, the Hanseatic league of cities that depended on them faded and the Dutch became the premier fishmongers of Europe for their turn. No one knows why the herring of the Baltic disappeared -- perhaps some change of conditions in the sea -- and they have never returned.

As yet, we have no way of adjusting to these fluctuations in natural populations of fishes in the sea. For example, while it is generally believed that the sardines of the California coast declined because of changes in the temperature of the ocean, brought about perhaps by changes in the currents, it is also suspected that a very heavy fishery at a period of unfavorable environmental change contributed to the decline of the fish stocks. Conversely, however, we have some evidence that a fairly heavy fishery of adults during favorable years might have the reverse effect -- that is, removing the mature large fish makes it possible for the young fishes to grow faster and replace the older ones that have been removed.

Whatever happens in nature, it is doubtful that major population changes are as simple as driving cattle off a range and turning sheep loose on it. Less than a hundred years ago it was believed by many eminent authorities on fisheries problems that the sea was so vast and the populations of fishes so immense that the efforts of man, however intense, could have no effect on the populations. It needed only a minute fraction of the population to replace the entire stock, so abundant is the spawn of most fishes. Now we have evidence concerning the extraordinary vulnerability of hatching and larval fish to changes in the environment -- how a drop of a degree or so of temperature may delay hatching perhaps several days, so that the egg drifts beyond the point of no return, or hatches at a time when other creatures that would eat it are just a little larger than they should be, and thus eat more fish. These small changes apparently have a way of piling up to produce unexpectedly large effects. And we have the example of the Baltic herring to suggest that the process may not always be reversible.

Mankind has had two great lessons concerning the effect of his fishing activities on the stock of fishes. The bottom fish of the North Sea and waters around the British Isles had been fished intensively up to 1914, and the catches were dropping off, and the average size of the fish was decreasing. Fishing had gone beyond that stage in the fishery when a harvest of the old mature fish enabled the smaller and younger ones to grow up to take their place -- the whole fisheries curve was dropping. But the war of 1914-18 made fishing impossible, and imposed a closed season on the stocks of the North Sea. When fishing was resumed in 1919, the fish were more abundant and larger. But man did not learn the lesson, and by 1938 things were back to where they were in 1914 -- or perhaps worse. Then World War 2 imposed another long closed season, and the stocks again improved. Now many nations that depend on the north sea fisheries have regulations requiring that the mesh of the nets be large enough for the smaller fish to escape, but in no field of international relations is uniformity and compliance so difficult to achieve as in fishery regulations.

When success is apparently attained, as in the halibut fishery of the United States and Canada, the suspicion arises in some minds that the fishery is not being regulated so much on conservation grounds as on lines to maintain the highest price for the fish. In any event, it was impossible for the fisheries experts to be certain that the halibut was being fished to capacity in the east Bering sea grounds, so in 1963 the Americans and Canadians grudgingly opened these grounds to Japanese fishing.

As we can see from the papers these days, we seem to be on the verge of some sort of crab war in the Bering sea with the Russians. More such controversies are inevitable as we increase our fisheries efforts, and it is certain that we will not be able to achieve a rational exploitation of the valuable fisheries stocks of the world ocean as long as the efforts of any one nation cannot be restricted. The efforts of those who agree to conserve Antarctic whales are futile as long as other fishing nations sneak into the waters and capture whales of all species and sizes. The United States cannot piously point the finger at another nation, especially in the matter of whales, for the memorial to the great pods of sperm whales, now forever gone from the seas, is New Bedford, Massachusetts. At least we have made some modest beginnings toward the sort of international accord that must be achieved in our cooperative international oceanographic endeavours. The most striking of these is now under way, the Internaional Indian Ocean Expedition. Under the auspices of the UN, this expedition which involves the ships and scientists of many nations, has as one of its aims the increase of knowledge about the resources of the Indian Ocean, primarily for the benefit of the countries bordering on the Indian Ocean. Some of these, like India, do not have the resources in research ships and talent to undertake such studies without this assistance.

It is difficult to predict which essential step toward greater reliance on the seas will come first -- complete international ccord or scientific understanding at such a level of sophistication that we can reasonably predict fisheries stocks from year to year. One suspects the latter will come first. Yet it is a difficult task, to understand the combined effects of man and nature in the sea. One of the greatest fisheries investigations in the history of man was that undertaken along the California and Oregon coast since about 1949 to find out what had happened to the sardines. As already mentioned, we are not sure how much of the change was brought about by nature and how much by man.

But we suspect most of the change was due to nature. This is based partly on the analogy of such past events as the 15th century disappearance of the Baltic herring, the great tilefish catastrophe of 1882, but in particular on the circumstance that while conditions seem to be improving for sardines and the fishing effort is minimal, the sardines are not coming back. Perhaps they will come back, but as yet we lack the information to predict if or when. We cannot even answer the question that we may have this whole business the wrong way around, that actually the great sardine catches of the 1930's were made during an unusual period and that the usual -- normal -- or average state of affairs is indeed one of colder waters, stronger winds and fewer sardines. So far, at least, we have no indication of regularity in this process -- cycles of 7, 9 or 11 years or whatever. What we do know is that the warming up of the ocean in 1957-60 is not a unique event -- something like it apparently occurred a hundred years before.

We are often asked about the warming of the ocean water, especially since this period seemed to coincide with more sharks. Perhaps it was simply that more people expose themselves to sharks these days. It is misleading to think of the ocean as warming up -- what actually happened was a shift in surface water, brought about by some change in the wind and pressure system over the entire Pacific basin. Decreased wind force reduces the upwelling of cold water near shore, and even results in somewhat higher sea level along the shore. If we try to understand the process as an actual warming up, we have to think of the amount of heat required -- something like four times the heat of the sun that actually reached the ocean in 1956-57. So evidently there was a shifting pattern in the ocean, and the sharks, out in the warmer waters away from shore all the time, simply moved in closer.

The changes we are talking about are of small magnitude as compared with the almost daily fluctuations on land -- the temperature rise in 1957-58 along central California was only about 3 degrees above the established average condition. The observed changes in marine life offer some evidence in support of what many naturalists have long suspected -- the life chains of the sea - from the floating diatoms to the great fish stocks are to be considered a system that is turning over at a rather high rate of speed - some of the smaller organisms have life cycles of a day or a few days, and the great blue whale, largest animal on earth, attains its full size in three or four years. But each level of the chain decreases in total mass as we proceed form the first producers to the last carnivores. There appears to be a great deal of lost energy in this system of turn over, and now and then the suggestion has been made that we should harvest our food from the lower levels -- the plankton -- instead of going to all the expense and uncertainty of catching fish. People who suggest this apparently do not realise that the plankton may be as equally spotty and uncertain.

Much more practical are the suggestions for the culture of these types of organisms that we can utilize at the second step -- such animals as clams and oysters. Oyster culture is our oldest marine industry -- practiced by the Romans. But shellfish and alga culture -- such as the green Chlorella for which so much was hoped a few years ago -- must be done in bays. We have given very little heed to the use of our bays except as cloaca maxima. If we should ever want to return San Francisco bay to a condition adequate for oyster culture, we would have an almost impossible clean up job on our hands. Some of the future proposals for water to Los Angeles, which include bypassing of unsatisfactory water from farmlands and industries into San Francisco Bay would make the possibility even more remote. San Francisco bay is gone -- as a scene for shellfish and seaweed culture. This is a local example of what we may allow to happen on a world wide basis while at the same time we talk about increasing our food supplies.

Another possibility is that we may domesticate whales and seals and a fanciful novel has been written about the great herds of whales controlled by electronic fences and of the divers that shepherd them about. It may be more practical to increase the nutrient content of shallow waters by stirring up the bottom with compressed air jets, or eliminating by chemical means some of the hordes of useless bottom animals like starfish that consume the greater part of the available food material that might instead support fish. Something along these lines has been suggested by Sir Alister Hardy, but admittedly we must be much more certain about the significance of these animals to the economy of the sea as a whole before we can proceed with confidence. Men's continuing war with the agricultural pests on land is in large part a problem of his own making -- by the intense cultivation of uniform crops he has set up attractive conditions for insects and viruses which in a state of undisturbed nature are only a small part of the system.

Today we have added a new variable to the uncertainties of the sea -- radioactive waste polution. Some of our Russian colleagues are of the opinion, and they may have some evidence for this -- that any degree of disposal of radioactive waste in the sea is potentially harmful, especially if it reaches the sea at those times when fish eggs are developing. This problem needs far more intensive study than it has so far received, even in England where studies are under way in the Irish Sea around the outfall of their infamous isotope sewer at Windscale.

We have such an isotope sewer of our own in the Columbia River, but the studies that should be made -- of the structure of fishes -- conditions of glands -- numbers of scales -- fin rays and vertebrae -- are yet to be made. It means nothing to catch a fish and measure its radioactivity if we do not look for possible damage. To take a fishes' background count and conclude it is not affected because it still swims around is misleading; we do know that fish get thyroid cancers or tumors from radioactivity. In examing the published work on the effects of radioactivity on marine organisms, one is struck by the preliminary -- progress report sort of atmosphere of these reports. When are we going to get down to some serious work on this problem? The editors of the Bulletin of Atomic Scientists may be justified in getting the hands of their clock back a few minutes, but this clock of pollution cannot be set back or halted, unless we are willing to accept our obligation to our environment more seriously than we so far done.

I have discussed the biological aspects of the inexahustible sea because I am a biologist. I can say little about other hopes expressed for man's future from the oceans -- the mining of manganese nodules from the deep, or of phosphorite from the waters around Los Angeles. A large chemical corporation did take out a lease to go after this material but found that its costs estimates were off by a factor of perhaps ten, and abandoned the effort. While the difficulties may not be unsurmountable, some of the desired resources must be in much shorter supply on land than they are now to make reclamation from the sea justifiable. Our best success so far has been with evaporating salt (another ancient industry), and obtaining magnesium from sea water. This is done on such a scale that the incidental fresh water obtained is now the principal water supply of an entire town in Texas. We have great hopes for fresh water from the sea -- or should we say Los Angeles has. But the prospect of economical fresh water from the sea is still so far off that we seriously discuss reducting most of the major rivers of this state to a shambles of dams and ditches to deliver water South of the Tehachapi. If we do manage to produce fresh water from the sea, will we tear up all these waterworks?

As for many of the fanciful submarine tractors, self prepelled nets and the like that have been suggested it must be remembered that the sea is a very difficult medium for machinery. It has enough salt to corrode but not enough to be a good conductor, and pressure makes it necessary to fill potentially collapsible spaces with incompressible fluids or construct heavy reinforcing against it. Most of the elaborate devices of the Sunday supplements have yet to leave the drawing boards, and the few that have been built, such as a self propelled submarine tractor, have been plagued with difficulties. The sea has long been a graveyard of fancy instruments. Someday, of course, our ingenuity will solve most of these problems and some of the fancy gadgets will go forth to find out how inexhaustible the sea really is. In the meanwhile we spend our money on atomic submarines -- how many of these things do we have now, anyway -- and on rockets to the moon. But, as one gentleman on a national scientific committee put it, it is still more essential for us to study the ocean's bottom rather than to scratch the moon's behind.

The National Research Council thinks our oceanographic budget should be 600 million by 1970; at present it is probably not more than 150 million per year and it is probable that the efforts by other countries are correspondly financed. This brings us to the final consideration in this notion concerning the inexhaustible sea -- we are not going to get much for nothing out of the sea. Man never has, for he has fished the sea at the peril of his life and loss of ships and gear. So far, in all the long history of fishing, we have used essentially the same gear that was used 1800 years ago. When we do devise some different way of catching fish than towing nets or dropping baited hooks, we will still face the essentially inhospitable environment of the sea, and will still remember the words of that first author on fishing concerning the lot of the fisherman:

> But for the toilsome fishermen their labors are uncertain, and unstable as a dream is the hope that flatters their hearts. For not upon the moveless land do they labor, but always they have to encounter the chill and wildly raging water.

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